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RELATION OF RATE OF CARDING AND FACTORS OF COTTON QUALITY TO STRENGTH AND APPEARANCE OF COMBED YARN, NEPS IN CARD WEB, CARD WASTE, AND COMBER WASTE

By

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CONTENTS

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16079

SUMMARY AND CONCLUSIONS

This is the fifteenth in the series of reports concerning the relationships of cotton fiber properties to performance in processing and quality of manufactured product. It is believed that these new findings fulfill certain gaps in existing knowledge concerning rate of card production as a factor in the textile processing of cotton, and that they provide a basis of assistance for making more comparable interpretations of experimental and commercial spinning data, identified with any rate of carding over a comparatively wide range for a given set of card settings and speeds, than heretofore has been possible.

Fiber and spinning data representing 8 American upland cottons, 2 American Egyptian cottons, and 1 Egyptian cotton, selected as being typical of 11 leading varieties grown in commercial production at the present time, were used in the correlation analyses of this study. The American upland and American Egyptian cottons originated from 6 States in the United States and the foreign cotton was grown in Egypt. The series of cottons ranged in staple length from 1-1/32 inches to 1-1/2 inches.

All cottons were processed from raw stock to spun yarn on the same textile equipment and by the same standard procedures. The settings, speeds, and rates of production were the same for all cottons in each of the two groups: (1) Upland; (2) Egyptian and American Egyptian. Processing details, however, differed in several particulars as between the two groups of cottons.

Each upland cotton was processed through the carding machine at 4 different rates of production; namely, 3.5, 6.5, 9.5, and 12.5 pounds per hour. The Egyptian and American Egyptian cottons were carded at 4 different rates of production; namely, 2.0, 3.5, 6.5, and 9.5 pounds per hour.

All lots of cotton at all rates of carding in the present study were processed through one and the same comber (Model D-4). A standard comber setting was used in all instances; namely, 0.48 inch between cushion plate and detaching roll.

Each of the 44 lots of cotton was spun into 3 sizes of combed yarn; namely, 36s, 50s, and 80s. All rovings and yarns were processed on long-draft equipment and the yarns represented a warp type of construction. A regular-draft, jack roving frame was used for the 80s yarn, in addition to the long-draft equipment. A semihard twist was used in spinning the yarns, the twist multiplier used being the optimum one for each cotton as determined by experimental test.

Twelve dependent variables were used in the respective correlation analyses, as follows: Strength of each 36s, 50s, and 80s combed yarn; count-strength product of all yarn sizes, collectively; appearance of each 36s, 50s, and 80s combed yarn; appearance of all yarn sizes, collectively; number of neps per 100 square inches of card web; percentage of card waste, comber waste, and total card and comber waste.

Ten independent variables in different combinations were used in the multiple correlation analyses, the variables being: Rate of carding; grade of cotton; sorter measurements of upper quartile length and coefficient of length variability; alternative fibrograph values of upper half mean length and length uniformity ratio; fiber fineness expressed as weight per inch; percentage of mature fibers; fiber strength; and yarn size.

Parallel analyses were made in all cases for each set of factors with a dependent variable: One including sorter length measurements; and the other, alternative fibrograph length values. A total of 134 statistical analyses was made: 24 multiple correlation analyses; and 110 simple correlation analyses.

Values obtained for coefficient of multiple correlation with each set of factors and dependent variable were as follows:

Dependent variable	Factors	Coefficient of correlation ($\bar{R}$)	
	Number	Sorter series	Fibrograph series
Strength of 36s yarn	7	0.989	0.994
Strength of 50s yarn	7	.984	.993
Strength of 80s yarn	7	.980	.988
CSP, all yarn sizes	8	.988	.993
Appearance of 36s yarn	7	.840	.874
Appearance of 50s yarn	7	.847	.871
Appearance of 80s yarn	7	.852	.827
Appearance, all yarn sizes..	8	.876	.885
Nep count of card web	7	.714	.743
Percentage of card waste ...	7	.869	.882
Percentage of comber waste..	7	.618	.767
Total card and comber waste.	7	.534	.694

Values for the percentage of total variance explained in each dependent variable by the factors used in the respective analyses were as follows:

Dependent variable	Factors	Variance explained ($\bar{R}^2$ x 100)	
	Number	Sorter series	Fibrograph series
Strength of 36s yarn	7	97.9	98.7
Strength of 50s yarn	7	96.8	98.6
Strength of 80s yarn	7	96.1	97.6
CSP, all yarn sizes	8	97.7	98.6
Appearance of 36s yarn	7	70.5	76.4
Appearance of 50s yarn	7	71.8	75.8
Appearance of 80s yarn	7	72.6	68.4
Appearance, all yarn sizes .	8	76.8	78.2
Nep count of card web	7	50.9	55.2
Percentage of card waste ...	7	75.4	77.8
Percentage of comber waste .	7	38.2	58.8
Total card and comber waste.	7	28.6	48.2

The relationship findings reported in this publication for strength of yarn are the best that have been obtained so far in this series of studies. These values exceed, by far, the general run of those previously reported in the published literature for the relations of cotton fiber properties to yarn strength.

The relative net effects of the respective factors to strength of various sizes of combed yarn were generally the same for both parallel analyses, including alternative fiber length measures. The principal factors contributing to strength of combed yarn, listed in order of descending importance, were as follows:

Dependent variable	Rank of factors
Strength of 36s yarn	Length, maturity
Strength of 50s yarn	Length, fineness, maturity
Strength of 80s yarn	Length, fineness, maturity
CSP, all yarn sizes	Length, yarn size, fineness, maturity

Rate of card production did not cause a statistically significant effect on strength of any size of combed yarn or on count-strength product of all sizes of combed yarn. In all cases, however, the beta values showed a negative sign--indicating a tendency for the strength of combed yarns to be slightly lower the faster the rate of card production.

The relative net effects of the respective factors to appearance of various sizes of combed yarn varied somewhat, depending on the size of yarn and whether sorter length measures or fibrograph length values were used in the corresponding analyses. The principal factors contributing to appearance of combed yarn, listed in order of descending importance, were as follows:

Dependent variable	Rank of factors (sorter series)
Appearance, 36s yarn..	Strength, fineness, rate of carding
Appearance, 50s yarn..	Strength, rate of carding
Appearance, 80s yarn..	Strength, length, rate of carding
Appearance, all sizes.	Strength, fineness, length, card rate, yarn size

Dependent variable	Rank of factor (fibrograph series)
Appearance, 36s yarn..	Fineness, strength, rate of carding, unif. ratio
Appearance, 50s yarn..	Fineness, strength, rate of carding, unif. ratio
Appearance, 80s yarn..	Fineness, strength, rate of carding
Appearance, all sizes.	Fineness, strength, rate of carding, yarn size, unif. ratio

Rate of card production caused a statistically significant effect on appearance of each size of combed yarn and on collective appearance of all sizes of yarn. In all cases, the beta values were accompanied by a negative sign--meaning the faster the rate of card production the lower was yarn appearance.

With the sorter series, rate of card production was the only factor that made a statistically significant contribution to number of neps per 100 square inches of card web. For the fibrograph series, however, 3 factors exerted a statistically significant effect on nep count of card web, ranking in order of descending importance as follows: Fineness; rate of card production; and grade. Both beta values of rate of carding carried a positive sign--indicating the faster the rate of carding the larger was the nep count of card web.

The relative net effects of the respective factors on percentage of manufacturing waste varied, depending on whether card waste, comber waste, or total card and comber waste was involved. For a given type of waste, the results from parallel analyses--including alternative fiber length measures--were somewhat inconsistent. The principal factors contributing to percentage of the different types of waste, listed in order of descending importance, were as follows:

Dependent variable	Rank of factor (sorter series)
Percentage of card waste	Fineness, rate of carding
Percentage of comber waste ...	Length, rate of carding
Total card and comber waste ..	Length

Dependent variable	Rank of factor (fibrograph series)
Percentage of card waste	Fineness, rate of carding, grade
Percentage of comber waste ...	Length, strength, grade, rate of carding
Total card and comber waste ..	Length, fineness, grade

A negative sign was attached to the beta values for rate of card production with percentage of card waste; a positive sign, with percentage of comber waste; and a negative sign, with total card and comber waste. These signs indicate that the faster the rate of carding the smaller was the percentage of card waste, the larger was the percentage of comber waste, and the smaller was the percentage of total card and comber waste. The effect of rate of carding, however, was statistically insignificant in the case of the last-named.

All results presented in this report were obtained from linear correlation analyses. No curvilinear correlation analyses were made in this study because the values obtained for the coefficients of multiple linear correlation were very large with most of the dependent variables and because previous analyses in this series of studies had shown no appreciable curvilinear relationships with any of the dependent variables, except percentage of picker and card waste from raw cottons representing a wide range of grades. The last-named condition, however, did not apply to percentage of card waste as considered in the present study because of the fact that all raw cottons included in these analyses represented the same general level of grade.

In the discussion part of this report, attention is directed to the importance of some background considerations of data entering into correlation analyses of this kind; emphasis is given to certain fluctuations in statistical values obtained from multiple correlation analyses, depending on whether sorter length measures or fibrograph length values are used; and pertinent results are reviewed from 20 literature citations on experimental and commercial carding of cotton and from 3 on experimental combing of cotton.

Supplementary to the correlation analyses reported herein, an exploratory study was made of the data by conventional methods of variance analysis. The results obtained from that method of approach, however, did not yield any information of an advantageous nature.

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INTRODUCTION

In the series of relationship studies on cotton fiber properties, 14 previous reports (29 through 42) 1/ have been published. The findings presented in the first six of those reports, together with a discussion of the broad problems and objectives involved, were summarized in a report in 1947 (28).

The 1952 publication in this series (42) contains results found for the relationship of rate of carding and six measurable elements of raw cotton quality to strength and appearance of carded yarn, to number of neps per 100 square inches of card web, and to percentage of card waste, as evaluated by multiple and simple correlation analyses. Neps of card web also were evaluated in their relationship to strength and appearance of various sizes of carded yarns. Those analyses represented 10 American upland cottons selected as being typical and representative of 10 leading varieties grown in commercial production at the present time. Each cotton was processed at 6 different rates of card production over a comparatively wide range. The settings and speeds within the carding machine were held constant for all cottons and for all rates of carding.

Parallel correlation analyses have now been completed on similar fiber and spinning data that recently became available from an extensive experiment with 8 American upland cottons, 1 Egyptian cotton, and 2 American Egyptian cottons. Each cotton was processed at 4 different rates of card production, using the same card settings and speeds with all cottons; each processed lot of cotton was passed through the comber at the same settings, speeds, and timing; and each lot of cotton was spun into the same 3 sizes of combed yarns over a practical range. Neps in card web were not considered in their relationship to strength and appearance of combed yarns, whereas they were in the case of carded yarns, because of the fact that the combing process removes most of the neps from the running stock. Any correlation values so obtained for neps, therefore, would possess little, if any, practical meaning and could serve no useful purpose.

The statistical values obtained from multiple and simple correlation analyses for the combed-yarn series representing 11 cottons are presented in this report, discussed briefly, and compared with similar findings for the carded yarn series of 10 cottons covered in the 1952 report (42). Twenty selected literature references are cited pertaining to the effects of card settings, speeds, and rates of production on cotton processing and quality of manufactured product; and three references are cited which show the effects of removing different percentages of comber waste, over a wide range, on fiber properties, cotton processing, and quality of manufactured product.

1/ Underscored numbers in parentheses refer to Literature Cited p. 38.

SAMPLES, TESTS, AND DATA

Fiber and spinning data identified with 11 cottons, selected as being typical and representative of 11 leading varieties grown in commercial production at the present time, served as the basis for the multiple and simple correlation analyses included in this study. All fiber and spinning tests were made in the laboratories of the Cotton Branch, Production and Marketing Administration, at Clemson College, S. C.

Source of Data

All fiber and spinning data used in these correlation analyses were part of those obtained from a study on the performance of a number of selected commercial varieties of cotton when processed at different rates of card production, as reported by Rouse and Burley (23).

Cottons

Cottons of different botanical origins were used in this study as follows: 8 American upland, 1 Egyptian, and 2 American Egyptian. They were grown commercially within their general areas of growth adaptation. The upland cottons were ginned on commercial saw gins serving their respective communities; the Egyptian and American Egyptian cottons were ginned on commercial roller gins. In an effort to obtain the most typical and representative cotton for each chosen variety, final selection of the experimental bale was made only after careful consideration of data obtained from fiber tests on samples representing a number of bales.

The cottons and varieties used in these analyses, together with their respective areas of growth, grade, and staple length designations, are shown in the following tabulation:

Type and variety	Area of growth	Grade	Staple length Inches
American upland:			
Coker 100 Wilt	South Carolina	SM	1-1/32
Deltapine	Mississippi	M	1-1/32
Empire Wilt	Georgia	M	1-1/32
Stoneville 2B	Missouri	M	1-1/16
Acala 1517	New Mexico	SMEW	1-1/8
Coker 100 Staple	Mississippi	SLM+	1-3/16
Mesilla Valley	New Mexico	SMEW	1-7/32
Wilds	Mississippi	M	1-1/4
Egyptian:			
Karnak	Egypt	1-1/2AE	1-7/16
American Egyptian:			
Pima 32	Arizona	2AE	1-15/32
Amsak	Arizona	1AE	1- 1/2

Four of the American upland cottons listed above were represented in the companionate statistical analyses for rate of carding with the carded yarn series as reported in 1952 (42). Those cottons which were common to both the carded and combed yarn studies were as follows: Coker 100 Wilt; Deltapine; Empire Wilt; and Acala 1517.

Measurements of the fiber properties of the experimental raw cottons are shown in table 1 (see Appendix) 2/. Complete fiber data for these raw cottons, including corresponding fiber data for their products at various stages of processing and for different types of manufacturing waste removed during processing, may be had by reference to the report of Rouse and Burley (23).

Processing of Cottons

All cottons were processed from raw stock to spun yarn on the same textile equipment and by the same standard procedures. Settings, speeds, and rates of production were the same for all cottons in each of the two groups: (1) Upland; and (2) Egyptian and American Egyptian; they differed slightly in several particulars, however, as between the two groups of cottons.

Each American upland cotton was processed through the carding machine at each of 4 rates of production; namely, 3.5, 6.5, 9.5, and 12.5 pounds per hour. The Egyptian and American Egyptian cottons were carded at each of 4 rates of production; namely, 2.0, 3.5, 6.5, and 9.5 pounds per hour.

All lots of cotton for all rates of carding were processed through one and the same comber (Model D-4). A standard comber setting was used in all instances; namely, 0.48 inch between cushion plate and detaching roll.

Three sizes of yarn were spun from each of the 44 lots of processed cotton; namely 36s, 50s, and 80s. All rovings and yarns were processed on long-draft equipment and the yarns represented a warp type of construction. A regular-draft, jack roving frame was used for the 80s yarn, in addition to the long-draft equipment. A semihard twist was used in spinning the yarns, the twist multiplier being the optimum one for each cotton, as based on maximum yarn skein strength obtained from trial tests made on the material carded at 6.5 pounds per hour.

Complete details concerning the processing organization, procedures, settings, and speeds used in converting these raw cottons into yarns are included in Rouse and Burley's report (23).

Rate of Carding

Rate of carding, as indicated previously, was used as an independent variable in all the multiple correlation analyses that were made.

2/ All tables are grouped in the Appendix at the end of this report and hereinafter they will be referred to only by table numbers.

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Fiber Properties

Six elements of raw cotton quality were used as independent variables in all the multiple correlation analyses of this study, as follows:

Fiber fineness, in micrograms per inch, as evaluated by the micronaire method.

Fiber strength, in terms of 1,000 pounds per square inch, as determined by the Pressley tester.

Percentage of mature fibers, as classified and counted on the basis of 2-to-1 lumen to wall ratio, after they had been permitted to swell in an 18-percent sodium hydroxide solution.

Grade of cotton, expressed as an index.

Upper quartile length, in inches, as determined by the sorter method.

Coefficient of length variability, in percent, as determined by the sorter.

(Alternative fiber length measures)

Upper half mean length, in inches, as determined by the fibrograph method.

Length uniformity ratio, in percent, as determined by the fibrograph.

The fiber tests relating to the data used in these analyses were those briefly described in the report for cotton testing service (27) and covered more broadly in the ASTM publication (2). Such laboratory data and statistical evaluations are considered more fully in the first and third reports of this series of relationship studies (29), (31).

Grade index was used in these correlation analyses, as explained in the report of this series having to do with the strength of 22s yarn, regular draft (35). The conversion chart for obtaining grade index values of samples of raw cotton, corresponding to various grade designations originally assigned, has been shown in previous reports of this series.

However, in view of the fact that two different sets of grade standards were required in the classification of these samples, in order to accommodate the different growths of cotton and different types of ginning involved, and that some apparent differences exist between the general levels of the two sets of standards, it was necessary, for the purpose of these statistical analyses, to make the original grade designations of the respective cottons conform to a common level.

In this connection, the best procedure appeared to be the conversion of the original grade designations of the Egyptian and American Egyptian samples to those of the Universal Standards for grade of upland cotton, principally on the basis of the quantity and type of foreign matter present, even though these factors were not strictly comparable throughout. With these limitations and reservations in mind, conversions were made in the original grade designations of the Egyptian and American Egyptian samples, as indicated for the tabulated values shown on page 16 in the report of 1947 (34), before affixing the corresponding grade index values used in these correlation analyses.

Neps in Card Web

Number of neps per 100 square inches of card web was used as a dependent variable in these correlation analyses.

The method for determining the number of neps per 100 square inches of card web was referred to briefly in the report for cotton testing service (27) and described more fully in the publication dealing with the relationship of neps to six elements of cotton quality (39). All nep counts of card web, identified with each of the different rates of card production, represented a standard weight card sliver of 40 grains per yard.

Card Waste

Percentage of card waste was used as a dependent variable in these analyses. The difference between the weight of stock fed to the card and the product delivered by it served as the basis for determining total loss in weight of stock at the card or total card waste. This value divided by the weight of the stock fed to the card and multiplied by 100 revealed the percentage of card waste removed by each of the rates of card production for the 11 cottons.

Comber Waste

Percentage of comber waste was used as a dependent variable in this study. The difference between the weight of stock fed to the comber and the product delivered by it constituted the basis for determining total loss in weight of stock at the comber or total comber waste. This value divided by the weight of the stock fed to the comber and multiplied by 100 showed the percentage of comber waste removed from the individual cottons, following processing at each of the 4 rates of card production used.

Card and Comber Waste

Percentage of total card and comber waste, representing the sum of the percentages of card waste and comber waste for each lot of cotton, was used as a dependent variable in these analyses. The sum of those percentages was a satistactory measure of total card and comber waste per cotton in this study, as all raw cottons were of the same general level in grade and as the percentage of picker waste was approximately the same in all cases.

Yarn Size

Along with the six elements of raw cotton quality listed, yarn size also was used as an independent variable in the multiple correlation analyses when count-strength product of all yarn sizes collectively was used as the dependent variable, and when appearance of all yarn sizes collectively was used as the dependent variable.

Yarn Properties

Yarn properties were used as respective dependent variables in these correlation analyses, as follows:

Strength of each 36s, 50s, and 80s yarn.
Count-strength product of all yarn sizes, collectively.
Appearance of each 36s, 50s, and 80s yarn.
Appearance of all yarn sizes, collectively.

Conventional skein strength tests of all yarns were made according to the generally adopted procedure described in ASTM Standards on Textile Materials (2) and used in USDA Cotton Testing Service (27).

Appearance of yarn was evaluated according to the standard for yarn appearance, as explained in the ASTM publication (2) and referred to in USDA Cotton Testing Service (27). Index values and adjective ratings for grades of yarn appearance were included in previous reports of this series.

STATISTICAL ANALYSES

The same general pattern of statistical analyses was followed in this study as that used in all the previous studies reported in this series. For more detailed information with regard to the statistical terms, measures, and techniques applied, see Appendix and consult the literature citations in the first and third reports in this series of studies (29), (31).

Beta coefficients were used to evaluate the relative net importance of the fiber properties to the various dependent variables instead of partial correlation coefficients, the latter of which were used in the early studies of this series. A correction factor was applied to the respective statistical values from all correlation analyses.

In this study, a total of 134 statistical analyses was made: 24 multiple correlation analyses; and 110 simple correlation analyses. Parallel analyses were made with each set of factors and dependent variable: One in which sorter length array measurements were used; and the other in which alternative fibrograph length values were substituted.

Values for the means, standard deviations, and ranges of the data for the respective independent and dependent variables included in the multiple and simple correlation analyses covered in this report are summarized in table 2. Tabulations of the basic fiber and spinning data, identified by cotton and by rate of card production, are shown in the report of Rouse and Burley (23).

RESULTS FROM MULTIPLE CORRELATION ANALYSES

Yarn Strength

Strength of 36s combed yarn. Tables 3 and 4 show that the multiple correlation coefficient for the 6 elements of raw cotton quality and rate of card production with skein strength of 36s combed yarn was 0.989 when sorter length measures were used and 0.994 when the alternative fibrograph length values were substituted. The respective $\bar{R}^2 \times 100$ values, also shown in tables 3 and 4, indicate that 97.9 percent of the variance in strength of 36s yarn was explained in the first case and 98.7 percent was accounted for in the second instance.

The relative net effects of the factors on the variance in strength of 36s combed yarn are shown in table 5 for the sorter series and in table 6 for the fibrograph series. Factors causing a statistically significant effect on strength of 36s combed yarn, ranked in order of descending importance, were as follows:

Sorter series	Fibrograph series
(1) Upper quartile length	(1) Upper half mean length
(2) Percentage of mature fibers	(2) Percentage of mature fibers
	(3) Grade index

Strength of 50s combed yarn. Tables 3 and 4 show that the multiple correlation coefficient for the 6 elements of cotton quality and rate of card production with skein strength of 50s combed yarn was 0.984 for the sorter series and 0.993 for the fibrograph series. As also shown in those two tables, the amount of variance in strength of 50s combed yarn explainable by the factors used in the two parallel analyses was 96.8 percent and 98.6 percent, respectively.

The relative net effects of the factors on the variance in strength of 50s combed yarn are shown in table 5 for the sorter series and in table 6 for the fibrograph series. Factors that made a statistically significant contribution to strength of 50s combed yarn, ranked in order of descending importance, were as follows:

Sorter series	Fibrograph series
(1) Upper quartile length	(1) Upper half mean length
(2) Fiber fineness	(2) Fiber fineness
(3) Percentage of mature fibers	(3) Percentage of mature fibers
	(4) Grade index

Strength of 80s combed yarn. The multiple correlation coefficient for the 6 elements of cotton quality and rate of card production with strength of 80s combed yarn was 0.980 for the sorter series and 0.988 for the fibrograph series, as shown in tables 3 and 4. On the basis of the $\bar{R}^2 \times 100$ values listed in those tables, 96.1 percent and 97.6 percent of the variance in the strength of 80s combed yarn were explainable by the factors used in the respective analyses.

The relative net effects of the factors on the variance in strength of 80s combed yarn are shown in table 5 for the sorter series and in table 6 for the fibrograph series. Factors causing a statistically significant effect on strength of 80s combed yarn, ranked in order of descending importance, were as follows:

Sorter series	Fibrograph series
(1) Upper quartile length	(1) Upper half mean length
(2) Fiber fineness	(2) Fiber fineness
(3) Percentage of mature fibers	(3) Percentage of mature fibers
	(4) Grade index

<u>Count-strength product of all sizes of combed yarn.</u> Tables 3 and 4 show that the multiple correlation coefficient for 6 elements of cotton quality, rate of card production, and yarn size with the count-strength product of all sizes of combed yarn collectively was 0.988 for the sorter series and 0.993 for the fibrograph series. The $\bar{R}^2 \times 100$ values listed in those tables indicate that 97.7 percent of the variance in count-strength product was explained by the factors in the sorter series and 98.6 percent of it in the case of the fibrograph series.

The relative contributions of the factors causing a statistically significant effect on count-strength product of all sizes of combed yarn collectively as shown in table 5 for the sorter series and in table 6 for the fibrograph series, ranked in order of importance, were as follows:

Sorter series	Fibrograph series
(1) Upper quartile length	(1) Upper half mean length
(2) Yarn size	(2) Yarn size
(3) Fiber fineness	(3) Fiber fineness
(4) Percentage of mature fibers	(4) Percentage of mature fibers
	(5) Grade index

<u>General (yarn strength).</u> Essentially the same high degree of correlation was found between the factors considered in the analyses and strength of each 36s, 50s, and 80s combed yarn, and collective count-strength product for those 3 sizes of combed yarn. For the sorter series the 4 values of coefficient of multiple correlation ($\bar{R}$) ranged only from 0.980 to 0.989 and those for the fibrograph series ranged only from 0.988 to 0.994. The values for the fibrograph series were slightly larger than those for the sorter series but the respective differences were statistically insignificant.

The statistical values obtained from multiple correlation analyses indicated that the factor of card-production rate caused no measurable effect on the variance in strength of combed yarns and in count-strength product of all sizes of combed yarn. Based on the values of beta coefficients listed in tables 5 and 6 for strength of 36s, 50s, and 80s combed yarn and for count-strength product of all sizes of combed yarn collectively, rate of card production ranked fourth to sixth among the factors considered in the sorter series and sixth to eighth in the fibrograph series. In all

cases, the values of the beta coefficients for rate of carding with strength of combed yarns and with count-strength product of combed yarns were statistically insignificant. In 3 out of the total of 8 cases, the beta values were so small as to be actually equal to or less than their respective standard errors and 5 of them were only slightly larger than their corresponding standard errors. Thus, all the evidence reported in tables 5 and 6 were highly consistent and convincing on the point that rate of carding caused no measurable effect on the strength of combed yarns.

The findings reported above with combed yarns were in contrast to those reported in 1952 (42) for the effect of rate of carding on the strength of carded yarns; that is, with carded yarn, the faster the rate of carding the lower was the yarn strength obtained. Although the reduction in strength of carded yarn caused by increasing the rate of carding was not large, it was measurable and consistent, as shown by statistically significant beta values in all 8 cases reported in 1952 (42) for rate of carding with strength of 14s, 36s, and 50s carded yarn and with count-strength product of all sizes of carded yarn. Those findings were obtained from the series of multiple correlation analyses which also included number of neps per 100 square inches of card web as an independent variable.

Presumably, the small reduction in strength of carded yarn resulting from increasing the rate of card production was caused by a combination of several considerations, as follows: (1) With increase in rate of carding, there is an opportunity for more fiber breakage to occur, particularly of the very long and of the extremely thin-walled types, with possible reduction in the mean fiber length of the processed stock and increase in its fiber length variability; (2) fewer short fibers and a smaller percentage of waste are removed from the stock being processed by the carding machine, the faster the rate of card production; (3) the fibers remaining in the running stock delivered by the card are straightened and parallelized to a lesser degree and they are in a less perfect condition for subsequent drafting and spinning processes, the faster the rate of card production; and (4) with increasing rates of carding, there is more opportunity and probability for structural injury occurring to more fibers and in greater degree than that at slower rates of card production.

Therefore, in the light of the new correlation findings presented in this report for strength of combed yarns, as compared with corresponding results previously reported for strength of carded yarns, it would appear that what the card does unfavorably or fails to do to cotton, during its processing at increasing rates of card production, is fully compensated for and overshadowed by the effects of the subsequent combing process.

Yarn Appearance

Appearance of 36s combed yarn. Tables 3 and 4 show that the multiple correlation coefficient for the 6 elements of raw cotton quality and rate of card production with appearance of 36s combed yarn was 0.840 for the sorter series and 0.874 for the fibrograph series. The respective R^2 x 100 values shown in those tables indicate that 70.5 percent of the variance in appearance of 36s combed yarn was explained by the factors in the analysis with the sorter length measurements and that 76.4 percent was accounted for in the analysis with fibrograph length values.

The relative net effects of the factors on the variance in appearance of 36s combed yarn are shown in table 7 for the sorter series and in table 8 for the fibrograph series. Ranked in order of descending importance, the statistically significant factors were as follows:

Sorter series	Fibrograph series
(1) Fiber strength	(1) Fiber fineness
(2) Fiber fineness	(2) Fiber strength
(3) Rate of carding	(3) Rate of carding
	(4) Length uniformity ratio

Appearance of 50s combed yarn. As shown in tables 3 and 4, the multiple correlation coefficient for the 6 elements of raw cotton quality and rate of card production with appearance of 50s combed yarn was 0.847 for the sorter series and 0.871 for the fibrograph series. The respective $\bar{R}^2$ x 100 values shown in those tables indicate that 71.8 percent of the variance in appearance of 50s combed yarn was explained in the first case and 75.8 percent was accounted for in the second instance.

The relative net effects of the factors on appearance of 50s combed yarn are shown in table 7 for the sorter series and in table 8 for the fibrograph series. In descending order of importance, the statistically significant factors ranked as follows:

Sorter series	Fibrograph series
(1) Fiber strength	(1) Fiber fineness
(2) Rate of carding	(2) Fiber strength
	(3) Rate of carding
	(4) Length uniformity ratio

Appearance of 80s combed yarn. The multiple correlation coefficient for the 6 factors of raw cotton quality and rate of card production with appearance of 80s combed yarn was 0.852 for the sorter series and 0.827 for the fibrograph series, as shown in tables 3 and 4. Also, listed in those tables are $\bar{R}^2$ x 100 values which indicate that 72.6 percent of the variance in appearance of 80s combed yarn was explained by the 7 factors in the case of the sorter series and 68.4 percent with the fibrograph series.

The relative net effects of the factors on appearance of 80s combed yarn are shown in table 7 for the sorter series and in table 8 for the fibrograph series. Listed in order of descending importance, the factors of statistical significance were as follows:

Sorter series	Fibrograph series
(1) Fiber strength	(1) Fiber fineness
(2) Upper quartile length	(2) Fiber strength
(3) Rate of carding	(3) Rate of carding

Appearance of all sizes of combed yarn. Tables 3 and 4 show that the multiple correlation coefficient for appearance of all sizes of combed yarn was 0.876 for the sorter series and 0.885 for the fibrograph series. The $\bar{R}^2$x 100 values listed in those tables indicate that 76.8 percent and 78.2 percent of the variance in such yarn appearance were explained by the factors used in the respective analyses.

The relative net contributions of the factors to appearance of all sizes of combed yarn are listed in table 7 for the sorter series and in table 8 for the fibrograph series. Factors causing a statistically significant effect in this respect, ranked in order of descending importance, were as follows:

Sorter series	Fibrograph series
(1) Fiber Strength	(1) Fiber fineness
(2) Fiber fineness	(2) Fiber strength
(3) Upper quartile length	(3) Rate of carding
(4) Rate of carding	(4) Yarn size
(5) Yarn size	(5) Length uniformity ratio

General (yarn appearance). Similar degrees of correlation were found for the factors considered in the analyses with appearance of each 36s, 50s, and 80s combed yarn, and with collective appearance of those 3 sizes of combed yarn. For the sorter series, the 4 values of coefficient of multiple correlation ($\bar{R}$) ranged from 0.840 to 0.876 and those for the fibrograph series ranged from 0.827 to 0.885. With one exception, the $\bar{R}$ values with the fibrograph series were slightly larger than those with the sorter series. The general differences, however, were so small as to be without any practical significance.

Other things being equal, the faster the rate of card production the lower was the resulting appearance of combed yarns. The factor of card production rate proved to be of appreciable importance to the appearance of 36s, 50s, and 80s combed yarn and to the collective appearance of all sizes of combed yarn. Rate of carding was about equal in importance to the appearance of each of those sizes of combed yarn, ranking fourth in all cases with the sorter series and third throughout with the fibrograph series. These findings with combed yarns are in contrast with those published in 1952 (42) for carded yarns, when rate of carding was found to be more important to the appearance of the finest carded yarn compatible with the staple length of a cotton than it was to the appearance of 14s or a relatively coarse yarn.

Of all the factors considered in the analyses on collective appearance representing all sizes of combed yarn, the factor of yarn size ranked only fifth with the sorter series and fourth with the fibrograph series. These findings are in contrast with those published in 1952 (42) for carded yarns; that is, of all the factors considered in the analyses with collective appearance representing all sizes of carded yarn, the factor of yarn size proved to be the most important one, by far.

Thus, on the basis of the new correlation findings presented in this report for appearance of combed yarns, as compared with results previously reported for appearance of carded yarns, it is evident that what the card does unfavorably or fails to do to cotton, during its processing at increasing rates of card production, is compensated for to a considerable degree by the subsequent combing process.

242937 O—53——3

Neps in Card Web

The coefficient of multiple correlation for 6 elements of raw cotton quality and rate of carding with number of neps per 100 square inches of card web, identified with the combed yarn series, was 0.714 for the sorter series and 0.743 for the fibrograph series, as shown in tables 3 and 4. According to the $\bar{R}^2$ x 100 values listed in those tables, 50.9 percent and 55.2 percent of the variance in nep count of card web were explained by the factors considered in the respective analyses.

The relative net effects of the factors on number of neps per 100 square inches of card web are shown in table 9 for the sorter series and in table 10 for the fibrograph series. Factors causing a statistically significant effect on nep count of card web, ranked in order of descending importance, were as follows:

Sorter series	Fibrograph series
(1) Rate of carding	(1) Fiber fineness
	(2) Rate of carding
	(3) Grade index

According to data in the 1952 report (42), it is evident that 3 factors made statistically significant contributions to nep count of card web identified with the carded yarn series, and that those factors, ranked in order of descending importance for both the sorter and fibrograph series, were as follows: Fiber fineness; rate of carding; and percentage of mature fibers.

On the basis of the foregoing findings, it must be concluded that the relations and relative importance of the factors to nep count of card web identified with the combed yarn series are somewhat different from those identified with the carded yarn series. Such, however, is not surprising in view of the fact that the two groups of cottons represented a number of different properties and conditions. For example, all cottons of the carded yarn series were ginned on saw gins. The 8 upland cottons of the combed yarn series also were ginned on saw gins. The 3 Egyptian and American Egyptian cottons of the combed yarn series, however, were ginned on roller gins. Moreover, the 10 cottons in the carded yarn series ranged in staple length from 29/32 inch to 1-1/8 inches and in fiber weight per inch from 3.8 micrograms to 5.6 micrograms, whereas the 11 cottons in the combed yarn series ranged in staple length from 1-1/32 inches to 1-1/2 inches and in fiber weight per inch from 3.0 micrograms to 4.7 micrograms. The mean and range values for percentage of mature fibers, however, were approximately the same for both series of cottons.

Finally, all cottons in the carded yarn series were carded at successively increasing rates of production from 2.0 pounds per hour to 15.5 pounds, whereas the 8 upland cottons of the combed yarn series were carded at rates of production ranging from 3.5 pounds per hour to 12.5 pounds and the 3 Egyptian and American Egyptian cottons were carded at rates of production ranging from 2.0 pounds an hour to 9.5 pounds. The number of neps per 100 square inches of card web averaged 21.9 for the carded yarn series, ranging from 4 to 98, whereas the nep count of card web for the combed yarn series averaged 39 and ranged from 7 to 160.

Manufacturing Waste

Card waste. As shown in tables 3 and 4, the multiple correlation coefficient for 6 elements of raw cotton quality and rate of carding with percentage of card waste was 0.869 for the sorter series; 0.882 in the fibrograph series. The $\bar{R}^2 \times 100$ values listed in those tables indicate that 75.4 percent and 77.8 percent of the variance in percentage of card waste were explained by the factors considered in the respective analyses.

The relative net effects of the factors on percentage of card waste are shown in table 9 for the sorter series and in table 10 for the fibrograph series. Listed in order of descending importance, the factors causing a statistically significant contribution ranked as follows:

Sorter series	Fibrograph series
(1) Fiber fineness	(1) Fiber fineness
(2) Rate of carding	(2) Rate of carding
	(3) Grade index

It may be noted from the foregoing that the rate of card production is the second factor of importance to the variance in percentage of card waste, being surpassed in both analyses only by fiber fineness, as expressed in terms of fiber weight per inch. The faster the rate of card production the smaller was the amount of waste removed by the carding machine, as indicated by the negative sign attached to the beta coefficients for rate of carding shown in tables 9 and 10. Both beta values for rate of carding are highly significant, being approximately 10 times their standard errors.

The grade factor was statistically insignificant to percentage of card waste in the case of the sorter series, the value of its beta coefficient being only slightly larger than its standard error. With the fibrograph series, the grade factor was barely significant, its beta value being slightly larger than 3 times its standard error. In the latter case, however, the sign attached to the beta value was "+" which means that the larger the grade index the larger was the percentage of card waste. The latter finding is not that ordinarily to be expected but is understandable in this instance.

More particularly, it should be emphasized that the grade factor and various other elements of raw cotton quality did--in fact--influence the relative level in percentage of card waste removed from each cotton at a given rate of card production. On the average, for individual cottons and blends of cotton representing a wide range of grades, the percentage of card waste increases with decrease in grade index, as identified with a particular processing organization. In this study, however, the grade factor was highly restricted, as called for by the specially designed rate-of-carding study that provided the basic data used in these correlation analyses. Grade of cotton in the practical or generally accepted sense, therefore, had little or no opportunity to influence the variance in percentage of card waste removed from these cottons.

In the previous rate-of-carding study identified with the group of 10 upland cottons that were shorter in fiber length on the whole than the cottons in this study and commonly processed into carded yarns, as reported in 1952 (42), neither grade nor any of the elements of cotton quality considered showed a statistically significant effect on the percentage of card waste. The beta values for all the quality factors with card waste in that instance were smaller than 3 times their respective standard errors. Rate of card production, however, caused a highly significant effect on percentage of card waste, as shown by its beta values from both the sorter and fibrograph series of analyses, being approximately 15 times their standard errors. The contribution of rate of carding to amount of card waste with the carded yarn series of cottons was so large as to over shadow the smaller contributions from any of the other 6 factors. Explanation for the disparity in correlation results with respect to card waste, as between the carded yarn series of cottons and the combed yarn series, is the same as that previously given for the findings pertaining to neps in card web.

In an earlier study in this series reported in 1947 (34), analyses were made on percentage of card waste in relation to the same 6 elements of raw cotton quality used in the present study, representing 150 long and extra-long staple cottons and including the following: 46 American upland, 9 SXP American Egyptian, 89 sea island, and 6 s. i. x A. u. hybrid cottons, crop years 1941-44. The upland cottons were saw ginned; all others were roller ginned. The carding machine was operated with conventional settings at 3 r.p.m. doffer speed in the case of the sea island samples, so as to furnish a 32-grain sliver with a rate of card production of 2.7 pounds per hour. In the case of the American Egyptian and upland samples, however, the card was operated at 4 r.p.m. doffer speed and produced a 36-grain sliver with a rate of card production of 3.6 pounds per hour.

As shown in the 1947 report (34), the multiple correlation coefficient for 6 elements of raw cotton quality and percentage of card waste when rate of carding was held approximately constant was 0.806, and 65 percent of the variance in percentage of card waste was accounted for by the 6 elements of cotton quality. Grade of cotton ranked outstandingly first in importance to percentage of card waste, as shown by a value for its partial correlation coefficient, being 10 times its standard error. Upper quartile length ranked second with a partial correlation coefficient of nearly 7 times its standard error. And fiber fineness ranked third with a partial correlation coefficient of 3 times its standard error.

By contrast with the above findings for those long and extra long cottons in the study of 1947 (34), the new findings from the present rate-of-carding study with long cottons may appear inconsistent and conflicting. Such a conclusion, however, is more apparent than real. For example, in the 1947 study (34) the 150 cottons possessed a comparatively wide range of grades and fiber properties. The grades extended from Good Middling to Good Ordinary with an average of Middling plus. That constituted a range of 6 grades according to the universal grade standards for American upland cotton and was equivalent to a range of 105 to 70 in terms of grade index, or 35 grade-index units. The grade-index of the cottons used in the present study, on the other hand, extended only from 96 to 105, and represented a range of merely 9 grade-index units.

Thus, in the study of 1947 (34) there was an opportunity for grade and the other elements of cotton quality to influence percentage of card waste to an extent that was impossible in the present study. Moreover, the factor of rate of carding used in the present study caused such a great effect on percentage of card waste that it overshadowed and minimized whatever effect on percentage of card waste that any of the cotton quality factors aside from fiber fineness otherwise and ordinarily would have had.

Comber waste. Tables 3 and 4 show that the multiple correlation coefficient for 6 elements of raw cotton quality and rate of carding with percentage of comber waste was 0.618 for the sorter series and 0.767 for the fibrograph series. The $\overline{R}^2 \times 100$ values listed in those tables indicate that 38.2 percent and 58.8 percent of the variance in percentage of comber waste were explained by the factors considered in the respective analyses.

The relative net effects of the factors on percentage of comber waste are listed in table 9 for the sorter series and in table 10 for the fibrograph series. Listed in order of descending importance, the factors causing a statistically significant contribution were as follows:

Sorter series	Fibrograph series
(1) Upper quartile length	(1) Upper half mean length
(2) Rate of carding	(2) Fiber strength
	(3) Grade index
	(4) Rate of carding
	(5) Percentage of mature fibers

It may be noted that rate of card production caused a statistically significant effect on percentage of comber waste as obtained from passing all lots of cotton processed at different rates of carding through a D-Model comber operated with one combination of settings and speeds throughout. With both the sorter and fibrograph series of analyses, however, the values of the beta coefficients of rate of carding were barely 3 times their respective standard errors. These barely significant findings for the effect of rate of carding on percentage of comber waste are in contrast to those for rate of carding in relation to percentage of card waste. The beta values for the effect of rate of carding on percentage of card waste, as previously referred to, were approximately 10 times their respective standard errors.

Another important difference exists between the beta values for rate of carding with percentage of card waste and with percentage of comber waste; namely, opposite signs. For card waste, a negative sign occurs which means that the faster the rate of card production the smaller the amount of card waste removed. For comber waste, however, a positive sign appears which indicates that the faster the rate of card production the larger was the quantity of comber waste removed by the standard procedure. Other things being equal, therefore, the smaller the amount of waste that the card removes during the processing of a cotton the larger is the quantity of waste available for the comber to remove; conversely, the larger the amount of waste that the card extracts during the processing of a cotton the smaller is the quantity of waste for the comber to remove.

Thus, on the basis of the new correlation findings presented in this report for card waste and comber waste, it is evident that what the card does unfavorably or fails to do to cotton, during its processing at increasing rates of card production, is compensated for to a considerable degree by the subsequent combing process.

In the 1947 correlation analyses for long stapled cottons and combed yarns (34), no consideration was given to percentage of comber waste as all the cottons were not processed through the combing machine by a standard procedure; that is, cottons occuring in different length groups were passed through the comber with different settings in an effort to approximate general practices followed in the textile industry. No statistical values identified with percentage of comber waste, therefore, are available from the 1947 study with which to compare the correlation values reported in this instance for percentage of comber waste.

Total card and comber waste. Tables 3 and 4 show that the multiple correlation coefficient for rate of carding and 6 elements of raw cotton quality with percentage of total card and comber waste was 0.534 for the sorter series and 0.694 for the fibrograph series. The $\bar{R}^2 \times 100$ values listed in those tables indicate that 28.6 percent and 48.2 percent of the variance in total card and comber waste were explained by the factors contained in the respective analyses.

The relative net effects of the factors on percentage of total card and comber waste are shown in table 9 for the sorter series and in table 10 for the fibrograph series. Factors causing a statistically significant contribution in this respect are listed, in order of descending importance, as follows:

Sorter series	Fibrograph series
(1) Upper quartile length	(1) Upper half mean length
	(2) Fiber fineness
	(3) Grade index
	(4) Percentage of mature fibers

General manufacturing waste. For both the sorter and fibrograph series of correlation analyses, the largest values for coefficient of multiple correlation ($\bar{R}$) were obtained with percentage of card waste, followed next by those with percentage of comber waste, and last by those with percentage of card and comber waste combined. These variations in degree of relation of rate of carding and 6 elements of raw cotton quality to the percentage of the respective types of manufacturing waste are explained on the basis of differences in level, distribution, and interactions of the measurements that enered into the analyses. In particular, the values for the mean and for the relative standard deviation of the percentages of the respective types of waste varied as follows:

Dependent variable	Mean Percent	Standard deviation Percent
Percentage of card waste............	7.10	16.5
Percentage of comber waste..........	15.08	10.9
Percentage of card and comber waste..	22.18	7.5

Thus, as the mean percentages of the different types of wastes increased and as the relative standard deviation of the respective wastes decreased, the values of the coefficient of multiple correlation ($\bar{R}$) decreased. Moreover, when percentage of total card waste and comber waste was used as the dependent variable, there was an automatic balancing out of the significant negative relation of rate of carding to percentage of card waste by the significant positive relation of rate of carding to percentage of comber waste. That such may and did occur is evident by the size of the beta values shown in tables 9 and 10 for rate of carding in relation to percentage of the different types of waste and by the signs attached to those respective beta values.

For example, there is a strongly significant negative relation between rate of carding and percentage of card waste, the two beta values being 10 to 11 times their respective standard errors; there is a small significant positive relation between rate of carding and percentage of comber waste, the two beta values being 3 to 4 times their respective standard errors; and there is no significance between rate of carding and percentage of total card and comber waste, the two beta values being only slightly larger than their respective standard errors. The beta values of the latter, however, carry a negative sign because of the fact that the negative relation with card waste was so much larger than was the positive relation with comber waste.

The values of multiple correlation ($\bar{R}$) obtained from the parallel analyses, including alternative fiber length measures, were approximately the same for card waste but they were noticeably larger for the fibrograph series in the case of comber waste as well as of total card and comber waste. The respective differences in $\bar{R}$ values, in favor of the fibrograph series, were as follows: Card waste, 0.013; comber waste, 0.149; card and comber waste collectively, 0.160. Explanation for the last two disparities is not readily apparent.

MULTIPLE REGRESSION EQUATIONS

Summaries of the multiple regression equations showing the relationship between the respective dependent variables and the collective independent variables are shown in table 11 when sorter length array measures were used and in table 12 when alternative fibrograph length values were included. These equations are not published as a basis for estimating or predicting yarn strength, yarn appearance, number of neps per 100 square inches of card web, percentage of card waste, percentage of comber waste, or percentage of total card and comber waste from a knowledge of values representing the respective factors included, because of the fact that each equation represented only 11 selected cottons: 8 American upland; 1 Egyptian; and 2 American Egyptian. Rather, the equations are presented merely to reveal the mathematical evaluation of the multiple relationships existing between the measures of the various factors used in the respective analyses.

From an examination of the equations shown in tables 11 and 12, it is evident that they vary appreciably for different dependent variables, as naturally would be expected. From a comparison of the corresponding equations identified with the fibrograph and sorter series, certain fluctuations and disparities may be noted. These fluctuations should be expected because the two methods of measuring length are entirely different, the fibrograph results being expressed on a number basis and excluding fibers shorter than 1/4 inch, whereas the sorter results are expressed on a weight basis and include fibers of all lengths in the sample.

Although upper half mean length and upper quartile length are correlated highly up to a certain point, their corresponding measures of length variability are expressed in different kinds of units--the fibrograph measure (length uniformity ratio) referring to the degree of fiber length uniformity in the longer half of the sample, that is, the larger the figure the more uniform will be the fiber lengths; and the sorter measure (coefficient of length variability) representing the degree of fiber length irregularity throughout the entire sample, that is, the larger the figure the more irregular will be the fiber lengths. Not only do the scales of values for fiber length uniformity and fiber length variability run in opposite directions but the values for uniformity ratio are about two to three times larger than those for coefficient of length variability.

The regression coefficients relating to the length factors, therefore, differ considerably. Those referring to the other variables used in the analyses and shown in the equations differ less, particularly the regression coefficients for rate of carding, percentage of mature fibers, fiber strength, and yarn size.

Pertinent information bearing on the multiple relationships occurring between the variables considered in the respective analyses, other than that already presented in the various tables of statistical values and discussed in other chapters, may be obtained from the regression equations. This is possible because of the fact that the respective regression coefficients in such equations serve to indicate directly the amount of change in a particular dependent variable caused, on the average, by one unit increase in each independent variable. The sign attached to a regression coefficient signifies whether a unit increase in the value of an independent variable produces an increase or decrease in the scale of values for the dependent variable.

In examining and comparing the values of the regression coefficients listed in tables 11 and 12, it should be remembered that different units of measurement necessarily had to be used for the various independent variables included in the statistical analyses, as shown in the following tabulation:

Independent variables	Unit of measurement
Rate of carding	1 lb. processed stock per hr.
Grade of cotton	1 index unit.
Upper quartile length.................	1 inch.
Upper half mean length	1 inch.
Coef. length variability..............	1 percent.
Length uniformity ratio	1 percent.
Fiber fineness........................	1 microgram per inch.
Mature fibers	1 percent.
Fiber strength	1,000 pounds per sq. in.
Number neps per 100 sq. in card web ...	1 unit.
Yarn size	1 yarn number.

As shown before, the unit of measurement for upper quartile length and for upper half mean length is 1 inch. Therefore, if the effect of upper quartile length or upper half mean length on a dependent variable is desired in terms of the more conventional units of 1/32-inch, as generally used in the cotton trade and textile industry, the regression coefficients shown in the equations for the length factors should be divided by 32. No further calculation or adjustment, however, is needed in connection with any of the other regression coefficients.

RESULTS FROM SIMPLE CORRELATION ANALYSES

The values for the coefficients obtained from simple correlation analyses, that is, when correlating only one factor or independent variable at a time with a dependent variable, are of interest in connection with a study of this kind. Such values refer to the relative gross effects of the respective factors on, or their comparative gross importance to, a particular dependent variable. As such, therefore, the values obtained from simple correlation analyses contrast with the values of the respective beta coefficients reported in tables 5, 6, 7, 8, 9, and 10 which represent the relative net importance of the respective factors to the various dependent variables.

When there is no appreciable degree of interrelationship existing between any of the independent variables, the values for a simple correlation coefficient denoting the magnitude of the gross contribution of a factor to a dependent variable, or its rank of importance to such, reasonably might be expected to be in general line with the findings identified with a corresponding beta coefficient denoting the magnitude of the net contribution of the same factor to the same dependent variable. More often than not, however, there are appreciable interrlationships occurring between various cotton fiber properties and associated factors which may cause the gross effect determined for a factor in such cases by simple correlation analysis to be larger than the net effect so evaluated for it by the beta coefficient, or to be smaller, or to be approximately the same. The fact that variations in the degree of relationship occur between the various pairs of fiber properties or independent variables considered, and that the relationship between the different pairs of independent factors are either positive or negative, give rise to accumulative and compensative effects in varying degrees and combinations, all of which influence the statistical values obtained when correlating one cotton fiber property or independent variable at a time with a particular dependent variable, as is done in simple correlation analyses.

The magnitude of gross effect and rank of gross importance of the various factors to the respective dependent variables representing the series of cottons, as evaluated by simple correlation analyses, are shown in the following three tables:

242937 O—53——4

Table 13--for strength of 36s, 50s, and 80s combed yarn and for count-strength product of all yarn sizes.

Table 14--for appearance of 36s, 50s, and 80s combed yarn and for collective appearance of all yarn sizes.

Table 15--for number of neps per 100 square inches of card web, for percentage of card waste, for percentage of comber waste and for percentage of total card and comber waste.

DIRECTION IN CONTRIBUTION OF RESPECTIVE FACTORS

The direction of the net effect of the respective factors used as independent variables in the multiple correlation analyses on the various dependent variables considered is shown by the signs attached to the beta coefficients listed in tables 5, 6, 7, 8, 9. and 10, and the direction of the gross effect of the factors is indicated by the signs attached to the coefficients of simple correlation ($\overline{r}$) reported in tables 13, 14, and 15. For purposes of convenience and assistance in visualizing this phase of the results, the beta values and their accompanying signs for each of the dependent variables correlated with all dependent variables are summarized in tables 16 to 23.

Rate of card production. From the data listed in table 16, it may be noted that the faster the rate of carding used in processing the 11 long and extra long staple length cottons included in this study the lower was yarn strength, the lower was yarn appearance, the larger was the number of neps per 100 square inches of card web, the smaller was the percentage of card waste, the larger was the percentage of comber waste, and the smaller was the percentage of total card and comber waste. The direction of the contribution of rate of carding was found to be consistent in all analyses for each dependent variable, whether the beta values were statistically significant or insignificant.

In all instances, the contribution of rate of carding was strong toward the appearance of combed yarns, toward nep count of card web, toward percentage of card waste, and toward percentage of comber waste. All beta values in these cases were statistically significant; that is, they were 3 or more times larger than their respective standard errors. In the cases of yarn strength and percentage of card and comber waste, however, all beta values for rate of carding were statistically insignificant. The insignificant beta values with percentage of total card and comber waste were owing, in large measure, to balancing out of the negative relationship occurring between rate of carding and percentage of card waste by the positive relationship existing between rate of carding and percentage of comber waste. The negative sign attached to the beta values for percentage of total card and comber waste was caused by the domination of the larger negative card-waste relationship with rate of carding over the smaller positive comber-waste relationshp with rate of carding.

In presenting these statistical evaluations of the effect of rate of card production on strength and appearance of combed yarn, on number of neps in card web, on percentage of card waste, comber waste, and total card and comber waste, the fact is appreciated that the relationships involved have been known, in a general sense, for many years; also that consideration of the adjustments for such relationships long have been dealt with, in a practical manner, by

commercial spinners in the textile industry. This is the first time, however, that the relationships and net effects of rate of card production and various factors of cotton quality have been statistically evaluated in combination, by such a comprehensive series of analyses and comparisons, with respect to combed yarns and processing performance for such a group of long and extra-long staple cottons as those included in the present study.

Fiber Maturity. As shown in table 17, the larger the percentage of mature fibers appearing in the raw cottons the higher was yarn strength, the better was yarn appearance, the smaller was the nep count of card web, the smaller was the percentage of card waste, the smaller was the percentage of comber waste, and the smaller was the percentage of total card and comber waste. The direction of the contribution of mature fibers was found, with one minor exception out of the total 24 cases, to be consistent in all parallel or alternative analyses for each dependent variable, whether the beta values were statistically significant or not, and to be in line with what normally might be expected.

In all instances, percentage of mature fibers in the raw cottons made a statistically significant contribution to strength of combed yarns, this variable occupying the position of either third or fourth rank of importance to combed-yarn strength, of the various factors included in the analyses. The effect of percentage of mature fibers of raw cotton on the appearance of each of the three sizes of combed yarn studied, however, was without statistical significance; likewise, percentage of mature fibers showed no statistical significance toward nep count of card web and percentage of card waste.

With percentage of comber waste, fiber maturity was found to exhibit a barely statistically significant effect in the analysis when fibrograph length values were included and no significant effect when sorter length data were used. Similar results were obtained with percentages of total card and comber waste. These are borderline cases and, as such, the reported inconsistencies are not considered to possess any significant or practical meaning.

In this connection, it may be pointed out that all but one of the cottons used in the rate-of-card production study that furnished the basic data for these analyses were considered to be average or better than average in fiber maturity and that the range of fiber maturity represented by these cottons was comparatively narrow. Table 1 shows that 9 of the raw cottons possessed a percentage of mature fibers ranging from 78 percent to 88 percent and that only one cotton contained as low as 66 percent. For all the cottons, the percentage of mature fibers averaged 82 percent and covered a range of 22 percent units. Thus, no highly immature samples, as defined in the report for cotton testing service (27), were included in these analyses. Fiber maturity in the generally accepted sense, therefore, did not have much of an opportunity to influence the variance in the dependent variables considered. If the study had included some highly immature cottons and represented a wider range of fiber maturity, a larger number of statistically significant effects, no doubt, would have been found for percentage of mature fibers on the various dependent variables.

An outstanding feature shown by the correlation results from this study for percentage of mature fibers, expressed on a 2-to-1 lumen to wall ratio basis, is the fact that, with only one minor exception, the direction of the contribution from this fiber property was found to be consistant in all instances with each dependent variable and, furthermore, that the evaluated directions were those normally to be expected. This had not been the case with all findings for fiber maturity as pointed out in earlier reports of this series. More particularly, in the report of 1952 (42) covering results for the rate-of-carding study identified with comparatively short staple cottons and carded yarns, the findings pertaining to fiber maturity were notably inconsistent and, in some cases, they were opposite to what ordinarily would be expected. For example, the signs attached to those beta values indicated that the larger the percentage of mature fibers the larger was the number of neps per 100 square inches of card web, the poorer was yarn appearance, and the lower was yarn strength. A probable explanation now appears as to why the correlation values for fiber maturity were better and more consistent in the case of the combed yarn series than those with the carded yarn series.

Attention first is invited to a report of 1951 (39) for a number of considerations and complexities bound up in the problem of cotton fiber maturity, together with various uncertainties at the present time in the practical measurement and meaning of that fiber property in actual relation to neps, processing performance, and quality of manufactured product. That report (39) pointed out that the method for evaluating cotton fiber maturity based on the 2-to-1 lumen to wall ratio, described by ASTM (2) and testing service (27), which has been used in the analyses covered in this report and all previous reports of this series, possesses certain limitations.

For some time, it has been suspected that the percentage of mature fibers, as determined by the standard method referred to above, was somewhat larger than what it should be; that the disparities varied appreciably between different samples; and that such inherent errors were significant from the standpoint of accuracy when attempting to evaluate the importance of fiber maturity in terms of spinning quality and product quality, as well as when trying to compare different growths and varieties of cotton on the basis of fiber maturity. Index values of fiber maturity obtained for 72 samples (53 American upland cottons and 19 selected cottons representing 4 other botanical species) by the new Causticaire method recently developed and reported by Burley and Bartmess (7), as compared with corresponding values derived for the same samples by the standard method, confirm those suspicions.

Moreover, evidence is now available to the effect that the nonrepresentative and inaccurate values heretofore obtained for percentage of mature fibers by the standard method were owing, in large measure, to the fact that the thin-walled fibers in the medium and shorter lengths of the sample did not enter into the tests and computations in proportion to the frequency of their occurrence. That is, a sizable number of the immature fibers in the shorter half of the sample were lost or disregarded by the procedure used in the past for sampling and preparing test specimens in connection with the standard fiber-maturity test.

Apparently, therefore, one of the principal reasons why better and more consistent correlation values were obtained for percentage of mature fibers with the combed yarn series, as here reported and covered in an earlier report (34), than those with various carded yarn series, as reported in 1952 (42) and in earlier reports of this series, was due to the

fact that a comparatively large percentage of the shorter thin-walled fibers were removed by the combing machine in textile processing. Elimination of such types of fibers in the form of comber waste or comber noils, thus, has the effect of making the percentage of mature fibers as determined by the standard method for raw cotton actually to be more representative of fiber maturity in the final processing of combed yarns than in the final processing of carded yarns.

This discovery of the cause for the unrepresentative and inaccurate values for percentage of mature fibers furnished by the long standing and widely used standard method, as explained in the foregoing, consitutes an important development in the field of cotton fiber technology. The new method developed by Burley and Bartmess (7) for evaluating cotton fiber maturity, which gives promise of yielding index values that are appreciably more representative, more accurate, and more significant with respect to cotton processing and product quality than heretofore had been possible by the old standard method, also constitutes an important development in the field of cotton fiber technology.

The two new developments referred to above appear to offer possibilities for making outstanding progress in the future measurement of cotton fiber maturity and, more particularly, in the evaluation of the true relations and importance of cotton fiber maturity to processing performance and quality of manufactured product. Results from future laboratory tests by the new cotton fiber maturity method (7) and findings from future correlation analyses including the new index values for cotton fiber maturity, therefore, are awaited with interest.

Fiber length. Beta values and accompanying signs for fiber length with each of the dependent variables are summarized in table 18. The longer the fiber, as measured by either the sorter or fibrograph method, the stronger was the combed yarn. All beta signs were positive and all beta values were statistically significant.

In the case of combed yarn appearance, all beta values for fiber length were negative; that is, the longer the fiber length, as measured by either the sorter or fibrograph method, the lower was the yarn appearance. All beta values for upper half mean length (fibrograph series) with yarn appearance were statistically insignificant and those for upper quartile length (sorter series) were statistically insignificant with the appearance of 36s and 50s combed yarn. With the appearance of 80s combed yarn and with the collective appearance of all sizes of such yarn, however, the beta values for upper quartile length were statistically significant. It is of interest to observe that the sorter upper quartile length made a statistically significant contribution to the appearance of 80s yarn and of all yarn sizes collectively, whereas fibrograph upper half mean length did not.

With increasing fiber length, as measured by either the sorter or fibrograph method, there was a tendency for the number of neps per 100 square inches of card web to be smaller. All beta values, however, were statistically insignificant. It is possible that the negative and statistically insignificant beta values may have been due to the fact that 3 of the longer bales (1 Egyptian and 2 American Egyptian) were roller ginned, whereas the other cottons of generally shorter lengths were saw ginned.

For the over-all series of 828 cottons, as reported in 1951 (39), the beta value for upper half mean length ranked first in importance to the number of neps in card web. The beta value was positive and statistically significant, being over 5 times its standard error. This

indicates that the longer the fiber, the larger is the number of neps per 100 square inches of card web. However, the beta values for upper half mean length tended to vary greatly, depending on different subgroupings of the cottons studied: Sometimes being plus; sometimes, minus; and often statistically insignificant, whether plus or minus.

Although both beta values for fiber length with percentage of card waste were statistically insignificant, they possessed a negative sign which indicates a tendency for a decrease in the proportion of card waste to occur with increase in fiber length.

With percentage of comber waste and with percentage of total card and comber waste, however, all beta values for fiber length were statistically significant and all signs attached to them were negative. Thus, as obtained for this series of cottons, there was statistically significant evidence to the effect that the longer the sorter upper quartile length or the longer the fibrograph upper half mean length the smaller was the percentage of comber waste identified with a standard comber setting and procedure, and the smaller was the percentage of total card and comber waste.

In this connection, it should be pointed out that 3 of the longer cottons of this series (1 Egyptian and 2 American Egyptian) were roller ginned, whereas the other 8 American upland cottons of generally shorter staple lengths were saw ginned. The factor of ginning, therefore, possibly exerted an influence and may have been largely responsible for the negative relationship found between fiber length and the different types of manufacturing waste included in the analyses.

Fiber length distribution. As shown by the data summarized in table 19, all beta values for sorter coefficient of fiber length variability with the various dependent variables were statistically insignificant, and all those for fibrograph uniformity ratio were statistically insignificant except for 3 dependent variables; namely, appearance of 36s, 50s, and all sizes of combed yarn collectively. In some instances, the signs of the beta values for fiber length distribution with the various dependent variables were those generally expected; in other cases, they were not.

The values of coefficient of fiber length variability (sorter) for the 11 cottons included in this study extended from 24 percent to 37 percent and covered a range of 13 units, which is considered to be a comparatively wide range. According to Cotton Testing Service (27), a value below 27 represents low variability and 35 or above represents high variability. The values for uniformity ratio (fibrograph) for the same cottons extended from 76 percent to 89 percent, covering a range of 13 units. According to Cotton Testing Service (27), a value above 80 for uniformity ratio represents high uniformity in fiber lengths and 75 to 80 represents average uniformity. Insignificant and inconsistent results obtained from the correlation analyses for the contribution from the measures of fiber length variability and uniformity ratio, therefore, cannot be attributed to the series of cottons having possessed a very narrow or highly restricted range in such values, as was the case with the series of cottons used in the 1952 study on rate of carding (42).

From a detailed examination of the data in table 19, it is evident that the signs attached to the beta values for fibrograph uniformity ratio are, in all cases, those normally to be expected with the various dependent

variables, whereas those for sorter coefficient of length variability are, in some cases, opposite to those to be expected. This observation, together with the fact that 3 of the 4 beta values for uniformity ratio and yarn appearance were statistically significant, whereas none of those for sorter coefficient of length variability were statistically significant, may suggest that the measure of uniformity ratio for raw cotton--by a series of circumstances--actually is more representative of fiber lengths in the final processing of combed yarns than is that of coefficient of length variability for raw cotton.

The inference advanced above is supported further by 3 considerations: (1) The combing process removes a relatively large proportion of the shorter fibers in running stock and appreciably improves the fiber length distribution of the shorter half of the sample; (2) The fibrograph method of test does not consider fiber lengths shorter than 1/4 inch and the measure of uniformity ratio represents only the ratio of two central tendencies, one of which is associated with the longer half of the sample; (3) By contrast, the sorter method of test includes all fiber lengths in the sample and the measure of coefficient of length variability represents the standard deviation based on squared deviations, weighted by the weight of fibers in their respective length intervals, and expressed as a percentage of the weighted mean length of the sample.

Fiber fineness. Table 20 shows a summary of the beta values and accompanying signs pertaining to fiber fineness in relation to the various dependent variables. The signs of the beta values were all consistent for the respective dependent variables, in both the sorter and fibrograph series of analyses; that is, the finer the fibers the stronger was the combed yarn, the coarser the fiber the better was the yarn appearance, the finer the fibers the larger was the nep count of card web, and the finer the fibers the larger was the percentage of card waste, comber waste, and total card and comber waste.

All the beta values for fiber fineness in the fibrograph series were statistically significant except 2; namely, with strength of 36s yarn and with percentage of comber waste. The 2 corresponding beta values in the sorter series also were statistically insignificant and, in addition, 4 other beta values in the sorter series were statistically insignificant. More beta values with statistical significance, therefore, were derived from the multiple correlation analyses including fibrograph length measurements than from those with sorter length values. Specific explanation for those disparities, however, is not readily available. Apparently, nevertheless, such disparities arise as the result of differences occurring in interactions between some of the various fiber measures used in the parallel analyses.

Fiber Strength. As shown by the data summarized in table 21, none of the beta values for fiber strength in relation to combed yarn strength were statistically significant and 6 out of the 8 cases showed a negative sign. Inconsistent signs with such small and statistically insignificant beta values are without any practical meaning and are not surprising. Even though the series of 11 cottons extended in fiber strength from 77,000 pounds to 106,000 pounds per square inch and represented a range of 29,000 pounds, the factor of fiber strength was not found to cause a statistically significant effect on yarn strength.

The foregoing is in contrast to the findings for fiber strength in relation to yarn strength from studies reported in previous publications of this series (29), (31), (34), (36), and (37). In those studies, however, the respective groups of cottons possessed a wider range of fiber strength and a lower minimum fiber strength than did the series of cottons used in the present study. For the 1935-37 series, fiber strength ranged from 53,200 pounds per square inch to 95,800 pounds; for the 1941-44 series, it extended from 70,000 pounds to 114,000 pounds; and, for the 1945-47 series, it ranged from 52,000 pounds to 109,000 pounds per square inch.

In this connection, it should be pointed out that all the cottons used in the present study were average or better than average in fiber strength. Apparently, therefore, the weakest cottons of the series had sufficient fiber strength for utilization in this series of 36s, 50s, and 80s combed yarn and that the increasing fiber strength of the other cottons did not influence yarn strength to any detectable degree. Although the products made from this series of cottons varied appreciably in yarn strength, the variance was caused primarily by variations in the factors of fiber length, fiber fineness, and fiber maturity, as previously discussed.

The stronger the fiber the better was yarn appearance. All beta values for fiber strength, from both the sorter and fibrograph series of analyses, were statistically significant and all signs attached to them were consistent.

Both beta values for fiber strength in relation to number of neps per 100 square inches of card web were statistically insignificant but each was accompanied by a negative sign. The latter indicates that the stronger the fiber the smaller was the nep count of card web.

The 3 beta values of fiber strength in relation to manufacturing waste were statistically insignificant in the case of the multiple correlation analyses using sorter length measures and 2 out of the 3 were likewise insignificant with the analyses including fibrograph values. For percentage of comber waste, however, the beta value for fiber strength was statistically significant when fibrograph length measures were used. The signs attached to the beta values derived from parallel analyses indicate that the stronger the fiber the smaller was the percentage of card waste, the larger was the percentage of comber waste, and the larger was the percentage of total card and comber waste.

Grade of cotton. All beta values for grade of cotton with all dependent variables were statistically insignificant in the case of the sorter series of analyses, as revealed by the data summarized in table 22. Variable signs were obtained, in the sorter series, for the beta values representing grade and strength and with appearance of different sizes of yarn. With the fibrograph series of analyses, all beta values for grade of cotton and yarn strength were statistically significant and one beta value out of four with yarn appearance was statistically significant. The signs, however, were negative with all beta values for yarn strength and yarn appearance.

With the fibrograph series, all beta values for grade of cotton with nep count of card web and with the different types of manufacturing waste were statistically significant, whereas none of them was in the parallel analyses using sorter length measures. In all cases,

however, a positive sign was attached to the beta values for grade in both series of analyses.

In all significant cases and in most insignificant cases, the direction of the evaluated contribution of grade of cotton to the respective dependent variables was opposite to that ordinarily expected from the grade factor. As previously stated, however, effort was made in the rate-of-card production study that furnished the basic data used in these correlation analyses to hold--for obvious reasons--the grade factor of the cottons as constant as possible. An opportunity, therefore, did not exist in these analyses for grade of cotton fully to express itself or to influence yarn appearance, yarn strength, neps in card web, and card waste in the usually accepted sense; that is, the range of grades possessed by the cottons used in these analyses was very restricted, the extreme range being only 9 index units, or extending only from 96 to 105, as shown in table 1. That range of grade index is equivalent to only 2-1/2 grade steps in terms of the Universal Grade Standards for American upland cotton; namely, Good Middling to Strict Low Middling plus.

Yarn size. Table 23 shows that a negative relation exists between yarn size and collective yarn appearance and between yarn size and collective count-strength product, as indicated by a minus sign attached to all beta values for those variables; that is, the larger the yarn number or the smaller the yarn size, the poorer was yarn appearance and the lower was count-strength product. In all the studies of this series, when yarn size was used as an independent variable in the analyses with either count-strength product of yarns (37), (41), (42) or yarn appearance (38), (40), (41), (42), highly consistent results were obtained for this factor as regards both magnitude and direction of its contribution. Presumably, that was true in all cases because of the fact that count-strength product and yarn appearance are so strongly influenced by yarn size, and that yarn size is entirely independent of any interrelationships existing between fiber properties or their measurements.

COMPARISON OF CORRELATION RESULTS OBTAINED FROM COMBED YARN SERIES WITH THOSE FROM CARDED YARN SERIES

In table 24, a summary is given of the values of coefficient of correlation obtained from multiple correlation analyses for 6 elements of raw cotton quality and rate of card production with various dependent variables, representing the carded yarn series of cotton studied in 1952 (42) and the combed yarn series of cottons in this study as well as differences in the values of the respective correlation coefficients for the two series of cottons. A corresponding summary is given in table 25 of the values for percentage of variance explainable in the various dependent variables, identified with the carded and combed yarn series, by the factors included in the respective analyses.

The results listed in table 24 show that the values of coefficient of correlation with yarn strength were slightly higher for the combed yarn series than for the carded yarn series, the difference values ranging from +0.023 to +0.040 for the sorter series and from +0.014 to +0.019 for the fibrograph series.

For yarn appearance, the values of correlation coefficients were somewhat lower for the combed yarn series than were those for the carded yarn series, the difference values ranging from -0.042 to -0.111 for the sorter series and from -0.033 to -0.090 for the fibrograph series.

In the case of number of neps per 100 square inches of card web, the values of the correlation coefficients are noticeably smaller for the combed yarn series than those for the carded yarn series, the difference values being -0.100 for the sorter series and -0.095 for the fibrograph series.

For percentage of card waste, the values of correlation coefficients were slightly smaller for the combed yarn series than were those for the carded yarn series, the difference values being -0.030 for the sorter series and -0.015 for the fibrograph series.

Expressed in another way, as shown in table 25, the factors used in the analyses explained more variance in the strength of combed yarns than in the strength of carded yarns, the difference values ranging from +4.6 percent to +7.9 percent in the case of the sorter series and from +2.8 percent to +3.7 percent with the fibrograph series.

The factors explained a smaller amount of variance in the appearance of combed yarns than in the appearance of carded yarns, the difference values ranging from -7.4 percent to -19.9 percent in the case of the sorter series and from -6.1 percent to -16.6 percent with the fibrograph series.

Less variance in nep count of card web was explained by the factors in connection with the combed yarn series of cottons than with the carded yarn series, the difference values being -15.3 percent for the sorter series and -15.0 percent for the fibrograph series.

Less variance in percentage of card waste was explained by the factors in connection with the carded yarn series than with the combed yarn series, the difference values being -5.5 percent for the sorter series and -2.7 percent for the fibrograph series.

Rate of carding did not cause a statistically significant effect on yarn strength and count-strength product in the combed yarn series, whereas it did produce a small statistically significant effect on yarn strength and count-strength product in the carded yarn series.

In considering the comparative correlation values reported, it should be remembered that a wider range of card-production rates and higher rates of card production were used with the carded yarn series of cottons than with the combed yarn series. The two studies and series of results, therefore, were not strictly comparable with respect to card-production rates, as shown in the following tabulation:

Series	Rate of carding, lb. per hour
Carded yarn:	
American upland	2.0, 3.5, 6.5, 9.5, 12.5, 15.5
Combed yarn:	
American upland	---, 3.5, 6.5, 9.5, 12.5, ----
Egyptian and American Egyptian	2.0, 3.5, 6.5, 9.5, ----, ----

The differences in rates of carding shown on the previous page for the two studies, no doubt, influenced the correlation results to some extent. General differences in staple length and other fiber properties of the two groups of cottons, as previously pointed out, also exerted their influences on the comparative statistical values. And, in the case of yarn strength and yarn appearance, the fact that one series of cottons was carded only and that the other series was both carded and combed further influenced the correlation findings.

DISCUSSION

The results obtainable from such correlation analyses as those reported in this publication will be no better, and can be no better, than the degree to which the cotton fiber, processing, and yarn-quality data used are accurate, comparable, and representative. Certain special reasons, however, are recognized for the exceptionally good correlation values presented in this report for the combed yarn series of cottons and in the report of 1952 (42) for the carded yarn series.

Background Considerations of Data Used in Analyses

In the first place, any differences in level of results between laboratories were eliminated from the respective groups of analyses by reason of the fact that all fiber, spinning, and yarn tests for the combed yarn series of cottons were made in PMA's laboratories at Clemson, S. C., whereas all those for the carded yarn series were made in PMA's laboratories at College Station, Tex. It is a recognized fact that, in spite of all the controls and checks available, when large numbers of cottons are processed and tested by the same procedures in various laboratories over an extended period of time, differences in level of results sometimes occur between laboratories. Obviously, tests made in one laboratory by one group of well-trained and thoroughly experienced technicians will offer more opportunity for yielding consistency and continuity in data than would be possible if the tests were made in 2 or more widely separated laboratories by different groups of workers.

Any sizable differences and variations in level of results, as referred to above, effect the results from correlation analyses when such data are combined and generally cause a lower degree of correlation being obtained for fiber properties with yarn qualities than otherwise would be the case. The fact that all tests for the combed yarn series in this study were made more or less consecutively in one laboratory by one group of workers within a relatively short period of time and that all tests for the carded yarn series in the 1952 study (42) were similarly made in one laboratory by one group of workers automatically eliminated any disparities in level of results between different laboratories and between different groups of workers. Removal of this type of variation from the basic data caused the correlation findings to be improved somewhat and the resulting statistical values to be better than would have been the case if the data from two or more testing laboratories had been combined in the respective analyses.

Moreover, highly standardized procedure are used in all of PMA's cotton fiber, spinning, and yarn testing laboratories; the sampling, conditioning, and testing of samples are carefully done and supervised; and periodic tests are made in the fiber and spinning laboratories on check-test samples whose calibration has been established by numerous

tests over a long period of time. As a result, therefore, the best possible cotton fiber, spinning, and yarn data are being obtained in PMA's laboratories. Obviously, any elimination of or reduction in personal equations associated with sampling and testing promotes improvement in the accuracy, significance, and reliability of such test data and all this, in turn, tends to cause the resulting correlation and statistical findings to be better than otherwise would be the case.

Finally, the distribution of the data that serve as the basis of correlation analyses influence the magnitudes of the statistical values obtained. Frequently, even though an extended range of cottons and a wide scatter of data may be involved in analyses, the observations are concentrated heavily around the respective mean values. In the present study with the combed yarn series, the 11 cottons ranged in staple length from 1-1/32 inches to 1-1/2 inches and the cottons were spaced rather regularly at intervals throughout that length range. In the carded yarn series of analyses (42), the 10 cottons ranged in staple length from 29/32 inch to 1-1/8 inches and were spaced throughout that length range. Thus, in these two studies and sets of correlation analyses, there was no concentration in the accepted sense of the various measurements of fiber properties around their respective mean values but, instead, the measurements for the most part were distributed quite regularly throughout their entire range. Under the circumstances, therefore, an opportunity existed for better correlation values being obtained in these instances than would have been the case if the measurements had been highly concentrated around their respective mean values as generally is the case for most analyses.

The position stated above is supported by findings obtained for the effect of concentration of data around the mean on the coefficient of multiple correlation, as referred to in reports (28), (29), and (34). More particularly, with the regional variety series of 384 lots of cotton, representing 16 varieties of cotton grown at 8 locations across the American Cotton Belt during 3 crop years, multiple correlation coefficients of 0.933 and 0.936 were obtained for the relations of 6 fiber properties to strength of 22s carded yarn and strength of 60s carded yarn, respectively. With selected subgroupings of cottons from this series, however, somewhat larger correlation values were obtained.

For example, with 25 cottons selected on the basis of their 22s yarn strength so that the value of each cotton consecutively increased approximately 4 pounds--starting with the minimum of 49 pounds and ending with the maximum of 142 pounds--a multiple correlation coefficient of 0.969 was obtained. With 25 cottons selected on the basis of 60s yarn strength so that the value of each cotton consecutively increased approximately 1 pound--starting at the minimum of 17 pounds and ending with the maximum of 43 pounds--a correlation coefficient of 0.984 was obtained. The foregoing findings illustrate well how even and uneven distribution of data included in the analysis can influence such correlation results.

Perhaps, by application of the best present-day methods of testing and by the use of currently available fiber-spinning-yarn-measurements, a multiple correlation coefficient in the region of 0.950 reasonably might be viewed as the highest attainable degree of relationship to be found between measurable cotton fiber properties and yarn strength when the statistical analysis is based on data

representing single observations or their equivalent; when relatively large numbers of observations or cottons are involved; when a wide range of varietal, locational, and seasonal effects are included; and when photochemical deterioration and microbiological decay of some of the fibers or samples occur in varying degrees. Larger multiple correlation coefficients, of course, reasonably might be expected from the use of data representing certain specific varieties of cotton, varietal means, mixes and blends of cotton, or other conditions of segregation and restriction imposed upon the data.

Findings from Analyses with Alternative Length Measures

For all dependent variables considered in connection with the combed yarn series except one, namely, appearance of 80s combed yarn, the values of the coefficients of multiple correlation ($\bar{R}$) were larger when fibrograph length values were used in the respective correlation analyses than when the alternative sorter length data were included. The differences were comparatively small and statistically insignificant, however, in all cases but two: Percentage of comber waste; and percentage of total card and comber waste. Explanation for the two large disparities is not readily apparent. All that may be said at the present time, therefore, is that such disparities did occur.

The values of beta coefficients shown in table 5, 6, 7, 8, 9, and 10, show that a larger number of statistically significant beta values occurred with the fibrograph series of 12 multiple correlation analyses than that with the corresponding sorter series of analyses. There were 48 statistically significant beta values with the fibrograph series, whereas there were only 31 with the sorter series, or a difference of 17 statistically significant beta values in favor of the fibrograph series of analyses. The mean number of statistically significant beta values for all 12 dependent variables, therefore, was 4.0 for the fibrograph series and 2.6 for the sorter series.

The breakdown of the foregoing differences, by dependent variable, is of further interest. In the case of strength of 36s, 50s, and 80s combed yarn and of count-strength product of all yarn sizes, one more statistically significant beta value occurred with the fibrograph series than with the sorter series, and in every instance the extra factor was grade. The other factors were the same for each dependent variable and ranked in the same order of importance regardless of whether sorter length measures or fibrograph length values were used in the analyses.

For the appearance of 36s combed yarn, one more significant beta value occurred for the fibrograph series than for the sorter series; two more in the case of the appearance of 50s combed yarn; no more in the case of the appearance of 80s combed yarn; and one more in the case of the appearance of all yarn sizes collectively. In all cases, fiber strength ranked first in importance to yarn appearance when sorter length data were used in the analyses, whereas fiber fineness ranked first in importance to yarn appearance when fibrograph length values were included. It was merely a case, in most instances, of fiber strength and fiber fineness reversing ranks of importance toward yarn appearance, as identified with the parallel analyses using alternative fiber length measures.

Several other observations are of interest in connection with the beta values of yarn appearance. For example, with appearance of 36s, 50s, and all sizes of combed yarn, uniformity length ratio (fibrograph) made a statistically significant contribution, whereas coefficient of length variability (sorter) did not made a statistically significant contribution to yarn appearance in any case. With appearance of 80s and all yarn sizes, on the other hand, upper quartile length (sorter) made a statistically significant contribution, whereas upper half mean length (fibrograph) did not make a statistically significant contribution to yarn appearance in any case.

With nep count of card web, percentage of card waste, comber waste, and total card and comber waste, the values obtained for beta coefficients show that grade made a statistically significant contribution in all cases when fibrograph length values were used in the analyses, whereas no single instance of such contribution was found when sorter length measures were included in the analyses. Fiber fineness made a statistically significant contribution to nep count of card web and to total card and comber waste, according to the beta values for the fibrograph series of analyses, but such was not the case with the sorter series of analyses. Fiber strength proved to be statistically significant to percentage of comber waste by the beta value obtained from the analysis with fibrograph data but not so with sorter data.

In this connection it is of interest to note that some disparities similar to those referred to above for the combed yarn series also were shown by the statistical values obtained for the same factors correlated with strength and appearance of carded yarn, as reported in 1952 (42), when alternative sorter length measures and fibrograph length values were used in the parallel analyses. More detailed consideration of those disparities, as identified with the respective dependent variables, may be had by reference to the 1952 report (42).

Why the foregoing differences in correlation results and statistical values should be, and what is the precise explanation for them are questions that cannot be properly answered at present. Those disparities merely emphasize, as repeatedly pointed out in this series of reports, that it is not the fiber properties per se that are being correlated in such analyses but, rather, the available measures used for the factors being considered. It is not surprising, of course, for different measures of a given fiber property, as evaluated by multiple correlation analyses, to show different degrees and ranks of importance to a particular dependent variable. But, it is somewhat surprising to find that the evaluated importance of some fiber properties which are common to all correlation analyses made-as, for example, grade of cotton, fiber fineness, and fiber strength--also varies in some cases when alternative measures for other fiber properties are included in the respective analyses--as, for example, sorter upper quartile length and coefficient of fiber length variability versus fibrograph upper half mean length and uniformity length ratio.

The foregoing forcefully illustrates several important points, as follows: (1) How complex the fundamental relationship problem bound up in cotton fiber properties and yarn qualities really is; (2) how fluctuating the evaluated importance of a given cotton fiber property toward a particular dependent variable can be on influences not only by different groups of cottons of various levels and ranges of

fiber properties, by different processing procedures, and by different sizes and constructions of yarns but also by the mere use of alternative measures for a certain fiber property or yarn quality; and (3) how difficult and dangerous it is to draw final conclusions and broad generalizations about such matters from data and analyses limited in number, nature, and scope. It should be understood, moreover, that it is--in fact--the scramble of all those stated and implied variables, interrelationships, limiting factors, tangibles, and intangibles that really go to make up the heart of the problem with respect to cotton fiber properties, insofar as their testing and evaluation in terms of processing performance and quality of manufactured product are concerned.

Carding of Cotton

As a basis for better understanding the findings covered in this report on cotton carding and those reported by other workers, information on the theory of carding published by Strang (25) is of interest. His discussion--supported by experimental data and 12 literature citations--includes a critical analysis of the action, interrelationships, and effects identified with various separate and collective parts of the carding machine.

The influence of rate of carding, that is, the number of pounds per hour of cotton processed through the carding machine in the course of textile manufacture, on the processing performance of cotton and on the quality of products manufactured from cotton has been known--in a general sense at least--for many years. Balls (3), in his pioneer studies over 25 years ago, made a very critical and comprehensive analysis of the action of the carding machine and its effects as defined in terms of various cotton fiber measurements, their frequencies and fractionations, and quality of manufactured product. In 1936, Spibey (24) reported the measured effects of a wide range of card-cylinder speeds on card wastes, slivers, and yarn for a Sakellaridis Egyptian cotton and for a Texas American cotton.

During the last 10 years, an extensive series of specialized experiments--all of a practical nature--have been made by various workers in different laboratories or commercial textile mills on the cause-and-effect relationships involved in the processing of a cotton through the carding machine. Emphasis has been given in most of these studies to the use of various settings and speeds in the carding machine, individually and in combination, in an effort to obtain an acceptable number of neps in card web as well as of favorable yarn appearance and yarn strength at a relatively high rate of card production.

In 1942, through a series of reports and abstracts, Dunlap (12), (13), (14), (16) reported that higher cotton yarn strength and better yarn appearance were obtained in a number of mills when the cylinder speed of cotton cards, equipped with either regular wire clothing or metallic clothing, were raised somewhat above those generally used in commercial practice. To have obtained a greater strength of yarn was worthy but to have obtained an increased card production with the same approximate yarn strength constituted an important step forward. Comparative test data for cottons processed with different flat and licker=in speeds on the card were reported by Dunlap (15) and referred to by Dunlap (17).

Goldman (18), in summarizing the results of his study, concluded that clean cotton will permit a heavier feed to the card, the use of higher card speeds, and will yield more production from cards than generally has been the record of commercial practice. On medium and coarse yarns, a production of 20 pounds per hour was obtained satisfactorily. Goldman (18) emphasized that, in processing cotton lint from the bale into yarn, it is the thoroughness of opening, cleaning, and lapping operations that controls the production rate of subsequent textile machines. He further pointed out that, in principle, the carding machine is only a long-draft reducing unit.

Cook and Willis (10) determined the effect of card speeds and production rates on the quality of yarn manufactured for each of 5 bales of American upland cotton of various grades, and on the processing performance of those cottons under such different conditions of card operation. Cook and Lee (11) evaluated the quality of combed yarns and processing performance, as effected by carding 4 American and Egyptian long staple cottons at different rates of production.

According to Grover and Dunlap (21), they were able to increase card production of cotton by 36 percent without significant loss in yarn strength. This was accomplished by increasing over-all card speed--changing cylinder speed from 165 r.p.m. to 225 r.p.m.--or by changing the weight of stock fed to the card and increasing doffer speeds. Such increased card speeds or production resulted in only one-third of a grade decrease in yarn appearance. Data of various kinds are presented in their report (21). The data were obtained by varying over-all card speeds, by changing only cylinder speeds, varying licker-in speeds, changing flat speeds, varying doffer speeds as well as weight of lap and weight of sliver. The final report covering Dunlap and Grover's studies on card production was published in 1945 (22).

The most comprehensive study on the performance of selected commercial varieties of cotton when processed at different rates of card production over a wide range was made in 1952 by Rouse and Burley (23). Eleven varieties of cotton were included in their carded yarn series and 11 varieties were included in their combed yarn series, 5 of the varieties being common to both series. The settings and speeds were held constant for all cottons within certain comparable groupings but they differed slightly in several particulars, as between groupings. Rate of card production, therefore, was accomplished by varying the rate of feed of stock to the carding machine--all other factors being held constant. Complete fiber data were presented by Rouse and Burley (23) for the raw cottons, for the products at various stages of processing, and for different types of card waste as well as for comber waste; also, complete data were included for yarn strength, yarn appearance, number of neps per 100 square inches of card web, and percentages of card waste, comber waste, and total card and comber waste. As previously stated, those data served as the basis of the correlation analyses covered in this report for the combed yarn series and for the carded yarn series reported in 1952 (42).

Bogdan and Feng (6) reported results obtained from extensive researches on cotton processing when using various settings and speeds in the carding machine, individually and in combination, and they recommended procedures for carding whereby an acceptable number of neps in card web as well as favorable yarn appearance and favorable yarn

strength may be obtained at a relatively high rate of card production. No consideration was given in their report, however, to the effect of rate of card production on those dependent variables at the optimum card settings and speeds which they recommended for a high rate of card production. Presumably, nevertheless, fewer neps in card web, better yarn strength, and better yarn appearance would result by use of their recommended card settings and speeds at lower rates of card production. The results reported by Bogdan and Feng (6), therefore, do not oppose or conflict with the findings relating to the performance of a number of selected cottons when processed at different rates of card production, as reported by Rouse and Burley (23), and they do not oppose or conflict with the relationship findings reported herein and in the 1952 report (42).

Bentley (4), (5), reported that with licker-in speeds of the carding machine increased from 517 r.p.m. to 795 r.p.m. no disadvantages were noted in processing 9,000,000 pounds of cotton at a commercial textile plant. Bentley (5) also stated that he obtained favorable processing results and yarn quality when carding cotton at the extremely high production rate of 25 pounds per hour. The settings and speeds being used by Bentley in the card are in general line with those recommended by Bogdan and Feng (6) for obtaining favorable results with high rates of card production. To obtain such results, however, it should be emphasized that it is necessary for the carding machine to be in practically perfect mechanical condition and balance, and for the settings to be more accurate than ordinarily is the case.

Combing of Cotton

Combing, the mechanical process used in the manufacture of fine cotton yarns and of medium and coarse numbers where exceptionally strong, clean, and smooth yarns are sought, is influenced by variables in the form of settings, speed, and timing. But, in this study, all lots of cotton for all rates of carding were processed through one and the same comber (Model D-4). A standard comber setting was used in all instances, namely, 0.48 inch between cushion plate and detaching roll. One standard procedure at the comber purposely was used in an effort to obtain the most comparable evaluations of the measurable effects on the processing and quality of yarns caused by carding the cottons at different rates of production. If one standard comber procedure has not been used in all cases, the measured effects of different rates of carding would have been masked or overshadowed, if not lost entirely.

The effects of removing various percentages of comber waste by small increments, extending from 0.57 percent to 24.20 percent, on the quality of cotton yarn were reported by Campbell and Cook (8), (9). One bale of selected American upland cotton--classified as Strict Middling in grade, 1-5/32 inches in staple length, and normal in character--was used in their study. Values were presented in their report for upper quartile length, mean length, coefficient of length variability, fiber fineness, and percentage of immature fibers identified with the comber sliver and with the comber noils, representing each of 9 different comber settings and 9 different percentages of comber-waste removal, as well as for the original comber lap and raw cotton involved.

By varying the percentage of comber waste removed, Campbell and Cook (8), (9), found that there was a general increase in the skein strength of 22s, 36s, and 60s yarn and that the strength of those sizes of yarn, representing removal of only 0.57 percent comber waste, actually was greater than the strength of the corresponding carded yarns. For the 60s yarn, the appearance was C+ for the carded yarn; B- for the combed yarns associated with 0.57 percent to 3.93 percent comber waste removal; B for the combed yarns identified with 7.77 percent to 19.81 percent comber waste removed; and B+ for the combed yarn representing an extraction of 24.20 percent comber waste. No trend in yarn appearance, however, was noted for 22s yarn with increasing percentage of comber waste extracted.

With an increase in the percentage of comber waste removed, Campbell and Cook (8), (9), reported that both upper quartile length and mean length of the fibers in the comber sliver increased in a fairly consistent manner. Variations between 0.57 and 24.20 percent of comber-waste removal showed that the upper quartile length of the comber sliver increased 0.017 inch, or about 1/64 of an inch, and at the same time the mean length increased 0.064 inch, or just over 1/16 of an inch. In other words, the mean length of the comber sliver increased more rapidly with increasing amounts of comber waste removed than did the upper quartile length, because of the fact that a larger amount of short fiber was removed as waste. This was definitely reflected in the values of coefficient of length variability, which gradually decreased from 27.06 to 20.89 percent as a result of approximately 24 percent more waste having been removed.

From the standpoint of the theory and objectives of combing, it is rather surprising to note from the foregoing results that even the most highly combed lot of cotton was no more uniform in fiber length than it was. The coefficient of length variability of 20.89 percent reported by Campbell and Cook (8), (9), was relatively good but their length array data showed that 39 percent of the fibers by weight in the most highly combed sliver in the test was 15/16 inch or shorter in length. At the same time, 41 percent of the fibers by weight in the comber noils was 1-1/16 inches or longer in length.

With regard to fiber fineness, Campbell and Cook's data (8), (9), for comber slivers and noils were fairly constant for the lots of cotton from which different amounts of comber waste were removed. Variations among the different lots of cotton tended to obscure any slight trend in fineness with increasing percentage of comber waste removed. It may be concluded, therefore, that insofar as their test was concerned, the combing process showed no significant tendency to segregate the fibers with respect to fiber weight per inch.

Campbell and Cook (8), (9), however, found that the combing machine appeared to be rather selective with respect to fiber wall type; that is, relatively more thin-walled or immature fibers occurred in the comber waste than in the comber sliver, and as the waste percentage increased the proportion of thin-walled fibers in the sliver tended to decrease. At the same time, the fibers in the waste became more "diluted" with thick-walled or mature fibers as the percentage of waste increased. If immature fibers are detrimental to the dyeing or mercerizing quality of the yarn or to the serviceability of the fabric, it is evident that the combing process causes some improvement in the stock from that standpoint.

A study on cotton combing along lines similar to the foregoing was made in England and reported in Platt's Bulletin in 1951 (1). In that study, one American upland cotton with a staple length of 1-3/16 inches was used and the respective amounts of comber waste removed were 5 percent, 9 percent, 13 percent, 21 percent, and 27 percent. Yarn of size 36s was spun from each lot of combed cotton and was tested for strength by both the skein and single-strand methods. It was found that each 5 percent increase in comber waste extracted led to a progressively reduced nep content. Yarn appearance was successively improved and the count-strength product was improved as more waste was removed. Each of the tests showed an increase in skein strength of approximately 4 percent over its immediate predecessor. The single strand tests showed a corresponding improvement in strength as the waste extraction was increased--the increase being of the order of 5 percent for each of the tests.

As regards the fiber properties measured in Platt's combing experiment (1), an increase in effective length from 1-3/16 inches to 1-5/16 inches was found to exist between the carded yarn and the combed yarn processed after removal of 10 percent comber waste. There was a significant increase in the mean fiber length between carded and combed yarn at 5 percent comber waste extraction, although above 5 percent there was no tendency toward further increase in mean length with this particular cotton. Similarly, the percentage of short fiber was significantly reduced between carded and combed material with a 5-percent comber waste extraction, but further increases in the amount of comber waste removed showed only a small reduction in the percentage of short fibers remaining in the material.

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APPENDIX

Table 1.--Summary of classification and fiber test results for 11 selected varieties of American upland, Egyptian and American Egyptian cottons, each of which was processed at 4 different rates of card production and each processed lot of which was spun into 36s, 50s, and 80s combed yarn

Type and variety of cotton	Area of growth	Classification: Grade	Classification: Staple length	Sorter: Upper quartile length	Sorter: Coefficient of length variability	Fibrograph: Upper half mean length	Fibrograph: Length uniformity ratio	Grade	Fiber weight per inch 1/	Mature fibers	Fiber strength
			Inches	Inches	Percent	Inches	Percent	Index	Micrograms	Percent	1,000 lbs. per sq. in.
American upland:											
Coker 100 Wilt....	S. Carolina	SM	1-1/32	1.17	29	1.05	81	104	4.7	84	79
Deltapine.........	Mississippi	M	1-1/32	1.22	32	1.05	78	100	4.6	88	78
Empire Wilt.......	Georgia	M	1-1/32	1.21	31	1.04	82	100	4.6	74	77
Stoneville 2B.....	Missouri	M	1-1/16	1.25	33	1.10	78	100	4.0	82	84
Acala 1517........	New Mexico	SMEW	1-1/8	1.33	29	1.14	79	104	4.0	78	82
Coker 100 Staple..	Mississippi	SLM+	1-3/16	1.27	37	1.10	77	96	3.8	85	84
Mesilla Valley....	New Mexico	SMEW	1-7/32	1.42	30	1.26	79	104	4.1	84	87
Wilds.............	Mississippi	M	1-1/4	1.50	29	1.33	76	100	3.2	66	90
Egyptian:											
Karnak............	Egypt	1-1/2AE	1-7/16	1.44	35	1.31	80	104	3.2	86	97
American Egyptian:											
Pima 32...........	Arizona	2AE	1-15/32	1.54	31	1.35	79	100	3.0	82	106
Amsak.............	Arizona	1AE	1-1/2	1.58	24	1.41	89	105	3.0	88	98
Mean..............	-------	----	1-7/32	1.36	31	1.19	80	102	3.8	82	87
Maximum...........	-------	----	1-1/2	1.58	37	1.41	89	105	4.7	88	106
Minimum...........	-------	----	1-1/32	1.17	24	1.04	76	96	3.0	66	77
Range.............	-------	----	15/32	.41	13	.37	13	9	1.7	22	29

1/ Determined by the micronaire method, as based on the curvilinear scale for American upland cotton and on the special scale for American Egyptian and Egyptian cottons.

Table 2.--Summary of statistical values representing the data identified with the various independent and dependent variables used in multiple and simple correlation analyses

Factors used in analysis, as--	Observations 1/	Value for-- Mean	Standard deviation Absolute	Standard deviation Relative	Maximum	Minimum	Range
	Number			Percent			
Dependent variables:							
Strength of 36s combed yarn, pounds	44	84.6	± 14.3	±16.9	109.4	65.5	43.9
Strength of 50s combed yarn, pounds	44	56.6	± 10.8	±19.1	76.4	41.9	34.5
Strength of 80s combed yarn, pounds	44	29.6	± 6.6	±22.3	41.8	20.6	21.2
Count-strength product of all yarn sizes, CSP units	132	2747	±599	±21.8	3938	1648	2290
Appearance of 36s combed yarn, index	44	101	± 16	±15.8	126	62	64
Appearance of 50s combed yarn, index	44	97	± 16	±16.5	121	60	61
Appearance of 80s combed yarn, index	44	89	± 16	±18.0	118	60	58
Appearance of all yarn sizes, index	132	96	± 17	±17.7	126	60	66
Neps per 100 square inches of card web, number	44	39	± 31	±79.5	160	7	153
Card waste, percent	44	7.10	± 1.17	±16.5	9.9	5.3	4.6
Comber waste, percent	44	15.08	± 1.64	±10.9	17.8	11.2	6.6
Card and comber waste, percent	44	22.18	± 1.66	± 7.5	25.3	17.9	7.4
Independent variables:							
Grade of cotton, index	44	102	± 3	± 2.9	105	96	9
Upper quartile length, inches	44	1.36	± .14	±10.3	1.58	1.17	.41
Coefficient of length variability, percent	44	31	± 3.3	±10.6	37	24	13
Upper half mean length, inches	44	1.19	± .13	±10.9	1.41	1.04	.37
Length uniformity ratio, percent	44	80	± 3.3	± 4.1	89	76	13
Fiber weight per inch, micrograms	44	3.8	± .6	±15.8	4.7	3.0	1.7
Mature fibers, percent	44	82	± 6.3	± 7.7	88	66	22
Fiber strength, 1,000 pounds per square inch	44	87	± 8.9	±10.2	106	77	29
Rate of carding, pounds per hour	44	7.3	± 3.4	±46.6	12.5	2.0	10.5
Yarn size, number	132	55.3	± 18.4	±33.3	80	36	44

1/ Values shown indicate the number of observations used in each multiple or simple correlation analysis (11 cottons each processed at 4 different rates of card production, and each processed lot of cotton spun into the same 3 sizes of combed yarn).

Table 3.--Statistical values obtained from multiple correlation analyses for six elements of raw cotton quality and rate of card production with yarn strength, with yarn appearance, with neps of card web, with percentage of card waste, with percentage of comber waste, and with percentage of card and comber waste (sorter length array data included in analyses)

Dependent variable	Independent variables 1/	Observations	Statistical value: $\bar{R}$	Statistical value: $\bar{R}^2 \times 100$	Statistical value: $\bar{S}$ Absolute 2/	Statistical value: $\bar{S}$ Relative 3/
	Number	Number		Percent		Percent
Strength of 36s combed yarn	7	44	0.989 ± 0.003	97.9	± 2.1	± 2.5
Strength of 50s combed yarn	7	44	.984 ± .005	96.8	± 2.0	± 3.4
Strength of 80s combed yarn	7	44	.980 ± .006	96.1	± 1.3	± 4.5
Count-strength product of all yarn sizes	4/ 8	132	.988 ± .002	97.7	±92.1	± 3.4
Appearance of 36s combed yarn	7	44	.840 ± .045	70.5	± 8.9	± 8.8
Appearance of 50s combed yarn	7	44	.847 ± .043	71.8	± 8.7	± 8.9
Appearance of 80s combed yarn	7	44	.852 ± .042	72.6	± 8.3	± 9.4
Appearance of all yarn sizes	4/ 8	132	.876 ± .020	76.8	± 8.1	± 8.5
Number of neps per 100 square inches of card web	7	44	.714 ± .075	50.9	±22.2	±56.7
Percentage of card waste	7	44	.869 ± .037	75.4	± .6	± 8.3
Percentage of comber waste	7	44	.618 ± .094	38.2	± 1.3	± 8.6
Percentage of card and comber waste	7	44	.534 ± .109	28.6	± 1.4	± 6.4

1/ The six elements of raw cotton quality included in the analyses were as follows: Upper quartile length; coefficient of fiber length variability; fiber fineness; fiber strength; percentage of mature fibers; and grade index.

2/ Unit varies with the dependent variable. For yarn strength, the result is in units of pounds; for count-strength product, it is in units of count-strength product; for yarn appearance, it refers to index units of yarn appearance; for number of neps per 100 square inches of card web, it is in terms of number of neps; and for percentage of card and comber waste, it is in units of percent.

3/ Absolute value of standard error ($\bar{S}$) divided by the respective mean value for the dependent variable, multiplied by 100.

4/ When count-strength product of all yarn sizes or appearance of all yarn sizes was used as the dependent variable, yarn size was included in the analysis as an independent variable.

Table 4.—Statistical values obtained from multiple correlation analyses for six elements of raw cotton quality and rate of card production with yarn strength, with yarn appearance, with neps in card web, with percentage of card waste, with percentage of comber waste, and with percentage of card and comber waste (fibrograph length data included in analyses)

Dependent variable	Independent variables 1/	Observations	Statistical value: $\bar{R}$	Statistical value: $\bar{R}^2 \times 100$	Statistical value: $\bar{S}$ Absolute	Statistical value: $\bar{S}$ Relative
	Number	Number		Percent	2/	Percent 3/
Strength of 36s combed yarn	7	44	0.994 ± 0.002	98.7	± 1.6	± 1.9
Strength of 50s combed yarn	7	44	.993 ± .002	98.6	± 1.3	± 2.3
Strength of 80s combed yarn	7	44	.988 ± .004	97.6	± 1.0	± 3.5
Count-strength product of all yarn sizes	4/ 8	132	.993 ± .001	98.6	±70.6	± 2.6
Appearance of 36s combed yarn	7	44	.874 ± .036	76.4	± 8.0	± 8.0
Appearance of 50s combed yarn	7	44	.871 ± .037	75.8	± 8.0	± 8.3
Appearance of 80s combed yarn	7	44	.827 ± .048	68.4	± 8.9	±10.0
Appearance of all yarn sizes	4/ 8	132	.885 ± .019	78.2	± 7.9	± 8.2
Number of neps per 100 square inches of card web	7	44	.743 ± .068	55.2	±21.22	±54.2
Percentage of card waste	7	44	.882 ± .034	77.8	± .56	± 7.9
Percentage of comber waste	7	44	.767 ± .063	58.8	± 1.06	± 7.0
Percentage of card and comber waste	7	44	.694 ± .079	48.2	± 1.21	± 5.5

1/ The six elements of raw cotton quality included in the analyses were as follows: Upper half mean length; length uniformity ratio; fiber fineness; fiber strength; percentage of mature fibers; and grade index.

2/ Unit varies with the dependent variable. For yarn strength, the result is in units of pounds; for count-strength product, it is in units of count-strength product; for yarn appearance, it refers to index units of yarn appearance; for number of neps per 100 square inches of card web, it is in terms of number of neps; and for percentage of card and comber waste, it is in units of percent.

3/ Absolute value of standard error ($\bar{S}$) divided by the respective mean value for the dependent variable, multiplied by 100.

4/ When count-strength product of all yarn sizes or appearance of all yarn sizes was used as the dependent variable, yarn size was included in the analysis as an independent variable.

Table 5.--Relative net importance of six elements of raw cotton quality, rate of card production and yarn size to the strength of long-draft processed combed yarn, as evaluated by multiple correlation analyses (sorter length array data included in analyses)

Variable	Observations	Rank	Beta coefficient 1/
	Number		
Strength of 36s combed yarn with:	44		
Upper quartile length		1	+0.627 ± 0.086
Fiber weight per inch		2	- .241* ± .081
Fiber strength		3	+ .140* ± .071
Percentage of mature fibers		4	+ .103 ± .027
Rate of carding		5	- .033* ± .023
Coefficient of length variability		6	+ .020* ± .037
Grade index		7	+ .014* ± .032
Strength of 50s combed yarn with:	44		
Upper quartile length		1	+ .603 ± .105
Fiber weight per inch		2	- .407 ± .099
Percentage of mature fibers		3	+ .136 ± .034
Rate of carding		4	- .019* ± .029
Fiber strength		5	- .012* ± .086
Grade index		6	+ .010* ± .039
Coefficient of length variability		7	- .003* ± .045
Strength of 80s combed yarn with:	44		
Upper quartile length		1	+ .669 ± .117
Fiber weight per inch		2	- .470 ± .110
Percentage of mature fibers		3	+ .168 ± .038
Fiber strength		4	- .141* ± .097
Grade index		5	- .032* ± .044
Rate of carding		6	- .027* ± .032
Coefficient of length variability		7	+ .007* ± .051
Count-strength product of all yarn sizes with:	132		
Upper quartile length		1	+ .557 ± .052
Yarn size		2	- .473 ± .013
Fiber weight per inch		3	- .329 ± .049
Percentage of mature fibers		4	+ .120 ± .017
Rate of carding		5	- .023* ± .014
Coefficient of length variability		6	+ .007* ± .022
Fiber strength		7	- .005* ± .043
Grade index		8	- .002* ± .019

1/ The sign indicates the direction of the contribution of the independent variable to yarn strength.

* Statistically insignificant, being less than 3 times its standard error.

Table 6.--Relative net importance of six elements of raw cotton quality, rate of card production and yarn size to the strength of long-draft processed combed yarn, as evaluated by multiple correlation analyses (fibrograph length data included in analyses)

Variable	Observations	Rank	Beta coefficient 1/
	Number		
Strength of 36s combed yarn with:	44		
Upper half mean length		1	+0.760 ±0.066
Fiber weight per inch		2	- .158*± .063
Fiber strength		3	+ .100*± .055
Percentage of mature fibers		4	+ .100 ± .022
Grade index		5	- .081 ± .023
Rate of carding		6	- .033*± .018
Length uniformity ratio		7	+ .017*± .023
Strength of 50s combed yarn with:	44		
Upper half mean length		1	+ .818 ± .068
Fiber weight per inch		2	- .267 ± .064
Percentage of mature fibers		3	+ .124 ± .023
Grade index		4	- .107 ± .023
Fiber strength		5	- .072*± .057
Length uniformity ratio		6	+ .052*± .023
Rate of carding		7	- .019*± .019
Strength of 80s combed yarn with:	44		
Upper half mean length		1	+ .856 ± .089
Fiber weight per inch		2	- .348 ± .085
Fiber strength		3	- .193*± .075
Percentage of mature fibers		4	+ .156 ± .030
Grade index		5	- .150 ± .031
Length uniformity ratio		6	+ .048*± .031
Rate of carding		7	- .026*± .025
Count-strength product of all yarn sizes with:	132		
Upper half mean length		1	+ .715 ± .039
Yarn size		2	- .473 ± .010
Fiber weight per inch		3	- .228 ± .037
Percentage of mature fibers		4	+ .112 ± .013
Grade index		5	- .100 ± .013
Fiber strength		6	- .050*± .033
Length uniformity ratio		7	+ .035*± .013
Rate of carding		8	- .023*± .011

1/ The sign indicates the direction of the contribution of the independent variable to yarn strength.

* Statistically insignificant, being less than 3 times its standard error.

Table 7.--Relative net importance of six elements of raw cotton quality, rate of card production and yarn size to the appearance of long-draft processed combed yarn, as evaluated by multiple correlation analyses (sorter length array data included in analyses)

Variable	Observations	Rank	Beta coefficient 1/
	Number		
Appearance of 36s combed yarn with:	44		
Fiber strength		1	+1.245 ±0.264
Fiber weight per inch		2	+ .909 ± .301
Upper quartile length		3	- .692*± .320
Rate of carding		4	- .628 ± .087
Coefficient of length variability		5	- .119*± .138
Percentage of mature fibers		6	+ .060*± .102
Grade index		7	- .056*± .120
Appearance of 50s combed yarn with:	44		
Fiber strength		1	+1.176 ± .258
Fiber weight per inch		2	+ .842*± .294
Upper quartile length		3	- .690*± .313
Rate of carding		4	- .630 ± .086
Coefficient of length variability		5	- .121*± .135
Percentage of mature fibers		6	+ .109*± .100
Grade index		7	- .048*± .117
Appearance of 80s combed yarn with:	44		
Fiber strength		1	+1.305 ± .254
Upper quartile length		2	- .964 ± .309
Fiber weight per inch		3	+ .735*± .290
Rate of carding		4	- .598 ± .084
Coefficient of length variability		5	- .119*± .133
Grade index		6	+ .046*± .116
Percentage of mature fibers		7	+ .043*± .099
Appearance of all yarn sizes with:	132		
Fiber strength		1	+1.181 ± .134
Fiber weight per inch		2	+ .789 ± .153
Upper quartile length		3	- .742 ± .163
Rate of carding		4	- .589 ± .044
Yarn size		5	- .307 ± .042
Coefficient of length variability		6	- .114*± .070
Percentage of mature fibers		7	+ .067*± .052
Grade index		8	- .019*± .061

1/ The sign indicates the direction of the contribution of the independent variable to yarn appearance.

* Statistically insignificant, being less than 3 times its standard error.

Table 8.--Relative net importance of six elements of raw cotton quality, rate of card production and yarn size to the appearance of long-draft processed combed yarn, as evaluated by multiple correlation analyses (fibrograph length data included in analyses)

Variable	Observations	Rank	Beta coefficient 1/
	Number		
Appearance of 36s combed yarn with:	44		
Fiber weight per inch		1	+1.287 ±0.268
Fiber strength		2	+1.163 ± .237
Rate of carding		3	- .612 ± .078
Length uniformity ratio		4	+ .373 ± .097
Grade index		5	- .250*± .097
Upper half mean length		6	- .234*± .281
Percentage of mature fibers		7	- .018*± .094
Appearance of 50s combed yarn with:	44		
Fiber weight per inch		1	+1.221 ± .271
Fiber strength		2	+1.080 ± .240
Rate of carding		3	- .617 ± .079
Length uniformity ratio		4	+ .336 ± .099
Grade index		5	- .228*± .098
Upper half mean length		6	- .212*± .284
Percentage of mature fibers		7	+ .044*± .095
Appearance of 80s combed yarn with:	44		
Fiber weight per inch		1	+1.146 ± .310
Fiber strength		2	+1.146 ± .274
Rate of carding		3	- .594 ± .091
Upper half mean length		4	- .366*± .325
Length uniformity ratio		5	+ .211*± .113
Grade index		6	- .088*± .112
Percentage of mature fibers		7	+ .032*± .109
Appearance of all sizes of yarn with:	132		
Fiber weight per inch		1	+1.160 ± .147
Fiber strength		2	+1.075 ± .130
Rate of carding		3	- .578 ± .043
Yarn size		4	- .307 ± .041
Length uniformity ratio		5	+ .293 ± .054
Upper half mean length		6	- .257*± .154
Grade index		7	- .181 ± .053
Percentage of mature fibers		8	+ .018*± .052

1/ The sign indicates the direction of the contribution of the independent variable to yarn appearance.

* Statistically insignificant, being less than 3 times its standard error.

Table 9.--Relative net importance of six elements of raw cotton quality and rate of card production to number of neps in card web, to percentage of card waste, and to total percentage of card and comber waste, as evaluated by multiple correlation analyses (sorter length data included in analyses)

Variable	Observations	Rank	Beta coefficient 1/
	Number		
Number of neps per 100 square inches of card web with:	44		
Fiber weight per inch		1	-1.028* ± 0.387
Fiber strength		2	- .790* ± .340
Rate of carding		3	+ .579 ± .113
Percentage of mature fibers		4	- .159* ± .132
Coefficient of length variability		5	- .155* ± .178
Grade index		6	+ .145* ± .155
Upper quartile length		7	- .109* ± .413
Percentage of card waste with:	44		
Fiber weight per inch		1	- .967 ± .274
Rate of carding		2	- .812 ± .080
Fiber strength		3	- .527* ± .241
Upper quartile length		4	- .366* ± .292
Grade index		5	+ .126* ± .109
Coefficient of length variability		6	- .085* ± .126
Percentage of mature fibers		7	- .084* ± .093
Percentage of comber waste with:	44		
Upper quartile length		1	-1.916 ± .462
Fiber strength		2	+ .943* ± .381
Fiber weight per inch		3	- .656* ± .434
Rate of carding		4	+ .381 ± .126
Percentage of mature fibers		5	- .243* ± .148
Coefficient of length variability		6	- .199* ± .199
Grade index		7	+ .178* ± .173
Percentage of card and comber waste with:	44		
Upper quartile length		1	-2.155 ± .500
Fiber weight per inch		2	-1.334* ± .469
Fiber strength		3	+ .561* ± .411
Percentage of mature fibers		4	- .301* ± .160
Grade index		5	+ .266* ± .187
Coefficient of length variability		6	- .257* ± .215
Rate of carding		7	- .198* ± .136

1/ The sign indicates the direction of the contribution of the independent variable to the dependent variable; namely, number of neps per 100 square inches of card web, percentage card waste, percentage comber waste, or total percentage of card and comber waste.

* Statistically insignificant, being less than 3 times its standard error.

Table 10.--Relative net importance of six elements of raw cotton quality and rate of card production to number of neps of card web, to percentage of card waste, to percentage of comber waste, and to total percentage of card and comber waste (fibrograph length data included in analyses)

Variable	Observations	Rank	Beta coefficient 1/
	Number		
Number of neps per 100 square inch of card web with:	44		
Fiber weight per inch		1	-1.354 ±0.369
Fiber strength		2	- .668* ± .326
Rate of carding		3	+ .575 ± .108
Upper half mean length		4	- .563* ± .387
Grade index		5	+ .476 ± .133
Percentage of mature fibers		6	- .194* ± .130
Length uniformity ratio		7	- .182* ± .134
Percentage of card waste with:	44		
Fiber weight per inch		1	-1.019 ± .260
Rate of carding		2	- .823 ± .076
Fiber strength		3	- .559* ± .230
Upper half mean length		4	- .360* ± .272
Grade index		5	+ .293 ± .094
Length uniformity ratio		6	- .173* ± .094
Percentage of mature fibers		7	- .050* ± .091
Percentage of comber waste with:	44		
Upper half mean length		1	-2.447 ± .369
Fiber strength		2	+1.178 ± .312
Fiber weight per inch		3	- .875* ± .352
Grade index		4	+ .413 ± .127
Rate of carding		5	+ .406 ± .103
Percentage of mature fibers		6	- .388 ± .124
Length uniformity ratio		7	+ .307* ± .128
Percentage of card and comber waste with:	44		
Upper half mean length		1	-2.676 ± .417
Fiber weight per inch		2	-1.587 ± .398
Fiber strength		3	+ .770* ± .352
Grade index		4	+ .616 ± .144
Percentage of mature fibers		5	- .420 ± .140
Length uniformity ratio		6	+ .181* ± .145
Rate of carding		7	- .180* ± .117

1/ The sign indicates the direction of the contribution of the independent variable to the dependent variable; namely, number of neps 100 square inches of card web, percentage of card waste, percentage of comber waste, or total percentage of card and comber waste.

* Statistically insignificant, being less than 3 times its standard error.

Table 11.--Summary of regression equations showing the relation between the respective dependent variables and the various independent variables, as developed from multiple linear correlation analyses of data representing 11 selected varieties of American upland, Egyptian, and American Egyptian cottons, ranging in staple length from 1-1/32 inches to 1-1/2 inches, each of which was processed at 4 different rates of card production and each processed lot of which was spun into the same 3 sizes of combed yarn (sorter length data included in analyses)

Estimate for dependent variable of--	Number of--		Regression equation involving--								
			Coefficient for independent variable of--								A
	Observations	Independent variables	X_{103} Rate of carding, lb. per hr.	X_{88} Grade of cotton, by index	X_2 Upper quartile length, in inches	X_3 Coefficient of length variability, in percent	X_{104} Fineness, micrograms per inch	X_{35} Percentage of mature fibers	X_{33} Strength in 1,000 lb. per sq. in.	X_{41} Yarn size, by number	Constant
(X'_{130}) Strength of 36s combed yarn, lbs. per skein	44	7	-0.137	+0.074	+ 64.772	+0.085	- 5.532	+ 0.233	+0.223	-------	- 29.81
(X'_{131}) Strength of 50s combed yarn, lbs. per skein	44	7	- .061	+ .042	+ 47.271	- .010	- 7.093	+ .233	- .015	-------	- 1.53
(X'_{25}) Strength of 80s combed yarn, lbs. per skein	44	7	- .051	- .079	+ 32.014	+ .013	- 5.003	+ .175	- .105	-------	+ 8.13
(X'_{40}) Count-strength product, all yarn sizes, CSP	132	8	-4.024	- .519	+2,419.096	+1.203	-317.903	+11.350	- .351	-15.462	+688.31
(X'_{126}) Appearance of 36s combed yarn, index	44	7	-2.966	- .339	- 81.428	- .588	+ 23.758	+ .154	+2.264	-------	- 15.87
(X'_{127}) Appearance of 50s combed yarn, index	44	7	-2.958	- .291	- 80.694	- .592	+ 21.862	+ .279	+2.125	-------	- 16.34
(X'_{128}) Appearance of 80s combed yarn, index	44	7	-2.728	+ .267	- 109.456	- .569	+ 18.538	+ .106	+2.292	-------	- 32.62
(X'_{129}) Appearance of all yarn sizes, index	132	8	-2.884	- .121	- 90.526	- .583	+ 21.386	+ .180	+2.227	- .281	- 6.05
(X'_{70}) Neps per 100 square inches of card web, number	44	7	+5.278	+1.703	- 24.695	-1.475	- 51.852	- .788	-2.774	-------	+412.76
(X'_{27}) Card waste, percent	44	7	- .277	+ .055	- 3.110	- .030	- 1.826	- .016	- .069	-------	+ 22.99
(X'_{74}) Comber waste, percent	44	7	+ .182	+ .109	- 22.756	- .099	- 1.732	- .063	+ .173	-------	+ 33.28
(X'_{125}) Total card and comber waste, percent	44	7	- .095	+ .164	- 25.866	- .130	- 3.557	- .079	+ .104	-------	+ 56.27

Table 12.--Summary of regression equations showing the relation between the respective dependent variables and the various independent variables, as developed from multiple linear correlation analyses of data representing 11 selected varieties of American upland, Egyptian, and American Egyptian cottons, ranging in staple length from 1-1/32 inches to 1-1/2 inches, each of which was processed at 4 different rates of card production and each processed lot of which was spun into the same 3 sizes of combed yarn (fibrograph length data included in analyses)

Estimate of dependent variable of--	Number of--		Regression equation involving--								
			Coefficient for independent variable of--								A
	Observations	Independent variables	X_{103} Rate of carding, lb. per hr.	X_{88} Grade of cotton, by index	X_{17} Upper half mean length, in inches	X_{19} Length uniformity ratio, in percent	X_{104} Fineness, micrograms per inch	X_{35} Percentage of mature fibers	X_{33} Strength, 1,000 lb. per sq. in.	X_{41} Yarn size, by number	Constant
(X'_{130}) Strength of 36s combed yarn, lbs. per skein	44	7	-0.138	- 0.431	+ 81.893	+0.073	- 3.638	+ 0.225	+0.160	-------	+ 7.28
(X'_{131}) Strength of 50s combed yarn, lbs. per skein	44	7	- .059	- .434	+ 66.846	+ .169	- 4.657	+ .213	- .088	-------	+ 15.88
(X'_{25}) Strength of 80s combed yarn, lbs. per skein	44	7	- .049	- .372	+ 42.695	+ .096	- 3.700	+ .163	- .143	-------	+ 22.41
(X'_{40}) Count-strength product, all yarn sizes, CSP	132	8	-3.952	-22.313	+3,235.468	+6.251	-219.833	+10.606	-3.349	-15.462	+1,804.17
(X'_{126}) Appearance of 36s combed yarn, index	44	7	-2.889	- 1.518	- 28.700	+1.823	+ 33.645	- .045	+2.115	-------	- 145.32
(X'_{127}) Appearance of 50s combed yarn, index	44	7	-2.895	- 1.374	- 25.774	+1.629	+ 31.701	+ .112	+1.952	-------	- 142.89
(X'_{128}) Appearance of 80s combed yarn, index	44	7	-2.711	- .514	- 43.318	+ .995	+ 28.911	+ .080	+2.012	-------	- 160.30
(X'_{129}) Appearance of all yarn sizes, index	132	8	-2.832	- 1.135	- 32.597	+1.482	+ 31.419	+ .049	+2.026	- .281	- 133.94
(X'_{70}) Neps per 100 square inches of card web, number	44	7	+5.240	+ 5.578	- 133.269	-1.717	- 68.335	- .963	-2.344	-------	+ 276.49
(X'_{27}) Card waste, percent	44	7	- .281	+ .128	- 3.186	- .061	- 1.923	- .009	- .073	-------	+ 19.33
(X'_{74}) Comber waste, percent	44	7	+ .194	+ .253	- 30.285	+ .151	- 2.311	- .101	+ .216	-------	+ 10.21
(X'_{125}) Total card and comber waste, percent	44	7	- .087	+ .382	- 33.471	+ .090	- 4.234	- .110	+ .143	-------	+ 29.55

Table 13.--Relative gross importance of six elements of raw cotton quality, including alternative fiber length measures, rate of card production, and yarn size, to the strength of long-draft processed combed yarn, as evaluated by simple correlation analyses

Variable	Observations	Rank	Correlation coefficient: $\bar{r}$ 1/	Correlation coefficient: $\bar{r}^2 \times 100$
	Number			Percent
Strength of 36s combed yarn with:				
Upper half mean length	44	1	+0.977 ± 0.007	95.4
Upper quartile length	44	2	+ .968 ± .009	93.8
Fiber weight per inch	44	3	- .942 ± .017	88.8
Fiber strength	44	4	+ .942 ± .025	88.7
Length uniformity ratio	44	5	+ .268* ± .141	7.2
Rate of carding	44	6	- .266* ± .142	7.1
Coefficient of length variability	44	7	- .244* ± .143	6.0
Grade index	44	8	+ .207* ± .146	4.3
Percentage of mature fibers	44	9	.000 ----	**
Strength of 50s combed yarn with:				
Upper half mean length	44	1	+ .976 ± .007	95.2
Upper quartile length	44	2	+ .963 ± .011	92.8
Fiber weight per inch	44	3	- .944 ± .016	89.2
Fiber strength	44	4	+ .923 ± .022	85.2
Length uniformity ratio	44	5	+ .293* ± .139	8.6
Coefficient length variability	44	6	- .251* ± .143	6.3
Rate of carding	44	7	- .246* ± .143	6.1
Grade index	44	8	+ .201* ± .146	4.0
Percentage of mature fibers	44	9	.000 ----	**
Strength of 80s combed yarn with:				
Upper half mean length	44	1	+ .963 ± .011	92.7
Upper quartile length	44	2	+ .955 ± .013	91.2
Fiber weight per inch	44	3	- .945 ± .016	89.3
Fiber strength	44	4	+ .908 ± .027	82.5
Length uniformity ratio	44	5	+ .272* ± .141	7.4
Rate of carding	44	6	- .246* ± .143	6.0
Coefficient of length variability	44	7	- .221* ± .145	4.9
Grade index	44	8	+ .147* ± .149	2.2
Percentage of mature fibers	44	9	.000 ----	**
Count-strength product of all yarn sizes with:				
Upper half mean length	44	1	+ .855 ± .023	73.1
Upper quartile length	44	2	+ .847 ± .025	71.7
Fiber weight per inch	44	3	- .831 ± .027	69.1
Fiber strength	44	4	+ .814 ± .029	66.3
Yarn size	44	5	- .467 ± .068	21.8
Length uniformity ratio	44	6	+ .264 ± .081	6.9
Rate of carding	44	7	- .243* ± .082	5.9
Coefficient of length variability	44	8	- .233* ± .083	5.4
Grade index	44	9	+ .192* ± .084	3.7
Percentage of mature fibers	44	10	.000 ----	**

1/ The sign indicates the direction of the gross contribution of the independent variable to yarn strength.

* Statistically insignificant, being less than 3 times its standard error.

** Imaginary (corrected $\bar{r}^2$ found to have a negative value).

Table 14.--Relative gross importance of six elements of raw cotton quality, including alternative fiber length measures, rate of card production, and yarn size, to the appearance of long-draft processed combed yarn, as evaluated by simple correlation analyses

Variable	Observations	Rank	Correlation coefficient $\bar{r}$ 1/	$\bar{r}^2$ x 100
	Number			Percent
Appearance of 36s combed yarn with:				
Rate of carding	44	1	-0.593 ± 0.099	35.1
Percentage of mature fibers	44	2	+ .347* ± .134	12.0
Length uniformity ratio	44	3	+ .281* ± .140	7.9
Upper quartile length	44	4	- .176* ± .148	3.1
Fiber weight per inch	44	5	+ .174* ± .148	3.0
Upper half mean length	44	6	- .088* ± .151	0.8
Coefficient of length variability	44	7	.000 ----	**
Grade index	44	8	.000 ----	**
Fiber strength	44	9	.000 ----	**
Appearance of 50s combed yarn with:				
Rate of carding	44	1	- .600 ± .098	35.9
Percentage of mature fibers	44	2	+ .388* ± .130	15.0
Length uniformity ratio	44	3	+ .278* ± .141	7.7
Upper quartile length	44	4	- .174* ± .148	3.0
Fiber weight per inch	44	5	+ .169* ± .148	2.8
Upper half mean length	44	6	- .079* ± .152	0.6
Coefficient of length variability	44	7	.000 ----	**
Grade index	44	8	.000 ----	**
Fiber strength	44	9	.000 ----	**
Appearance of 80s combed yarn with:				
Rate of carding	44	1	- .568 ± .103	32.2
Percentage of mature fibers	44	2	+ .366* ± .132	13.4
Upper quartile length	44	3	- .220* ± .145	4.9
Fiber weight per inch	44	4	+ .198* ± .147	3.9
Length uniformity ratio	44	5	+ .189* ± .147	3.6
Upper half mean length	44	6	- .120* ± .150	1.4
Coefficient of length variability	44	7	.000 ----	**
Grade index	44	8	.000 ----	**
Fiber strength	44	9	.000 ----	**
Appearance of all yarn sizes with:				
Rate of carding	44	1	- .566 ± .059	32.0
Percentage of mature fibers	44	2	+ .366 ± .076	13.4
Yarn size	44	3	- .295 ± .080	8.7
Length uniformity ratio	44	4	+ .264 ± .081	7.0
Upper quartile length	44	5	- .214* ± .083	4.6
Fiber weight per inch	44	6	+ .206* ± .084	4.2
Upper half mean length	44	7	- .148* ± .085	2.2
Coefficient of length variability	44	8	+ .056* ± .087	0.3
Grade index	44	9	.000 ----	**
Fiber strength	44	10	.000 ----	**

1/ The sign indicates the direction of the gross contribution of the independent variable to yarn appearance.

* Statistically insignificant, being less than 3 times its standard error.

** Imaginary (corrected $\bar{r}^2$ found to have a negative value); rank based on uncorrected r values.

Table 15.--Relative gross importance of six elements of raw cotton quality, including alternative fiber length measures and rate of card production, to number of neps in card web, to percentage of card waste, to percentage of comber waste, and to total percentage of card and comber waste

Variable	Observations	Rank	Correlation coefficient $\bar{r}$ 1/	Correlation coefficient $\bar{r}^2$ x 100
	Number			Percent
Number of neps per 100 square inches of card web with:				
Rate of carding	44	1	+0.558 ± 0.105	31.1
Percentage of mature fibers	44	2	- .349* ± .134	12.2
Coefficient of length variability	44	3	- .152* ± .149	2.3
Length uniformity ratio	44	4	- .112* ± .151	1.3
Upper quartile length	44	5	.000 ----	**
Fiber weight per inch	44	6	.000 ----	**
Fiber strength	44	7	.000 ----	**
Grade index	44	8	.000 ----	**
Upper half mean length	44	9	.000 ----	**
Percentage of card waste with:				
Rate of carding	44	1	- .818 ± .051	66.9
Fiber weight per inch	44	2	- .358* ± .133	12.8
Upper half mean length	44	3	+ .292* ± .139	8.5
Upper quartile length	44	4	+ .291* ± .140	8.5
Fiber strength	44	5	+ .265* ± .142	7.0
Coefficient of length variability	44	6	.000 ----	**
Grade index	44	7	.000 ----	**
Percentage of mature fibers	44	8	.000 ----	**
Length uniformity ratio	44	9	.000 ----	**
Percentage of comber waste with:				
Upper half mean length	44	1	- .411 ± .127	16.9
Upper quartile length	44	2	- .392 ± .129	15.4
Rate of carding	44	3	+ .371* ± .131	13.8
Fiber weight per inch	44	4	+ .231* ± .144	5.4
Fiber strength	44	5	- .199* ± .146	4.0
Coefficient of length variability	44	6	+ .155* ± .149	2.4
Grade index	44	7	.000 ----	**
Percentage of mature fibers	44	8	.000 ----	**
Length uniformity ratio	44	9	.000 ----	**
Percentage of card and comber waste with:				
Upper half mean length	44	1	- .128* ± .150	1.7
Rate of carding	44	2	- .113* ± .151	1.3
Upper quartile length	44	3	- .100* ± .151	1.0
Coefficient of length variability	44	4	.000 ----	**
Percentage of mature fibers	44	5	.000 ----	**
Grade index	44	6	.000 ----	**
Fiber strength	44	7	.000 ----	**
Length uniformity ratio	44	8	.000 ----	**
Fiber weight per inch	44	9	.000 ----	**

1/ The sign indicates the direction of the gross contribution of the independent variable to the dependent variable, namely percentage of card waste, percentage of comber waste, total percentage of card and comber waste, or neps in card web.

* Statistically insignificant, being less than 3 times its standard error.

** Imaginary (corrected $\bar{r}^2$ found to have a negative value); rank based on uncorrected r value.

Table 16.--Summary of relative net importance of rate of card production to various dependent variables, as evaluated by multiple correlation analyses

Dependent variable	Rate of card production with--					
	Sorter series			Fibrograph series		
	Rank	Beta coefficient 1/	Statistically significant	Rank	Beta coefficient 1/	Statistically significant
Strength of:						
36s combed yarn, pounds	5	-0.033	No	6	-0.033	No
50s combed yarn, pounds	4	- .019	No	7	- .019	No
80s combed yarn, pounds	6	- .027	No	7	- .026	No
All combed yarn, CSP	5	- .023	No	8	- .023	No
Appearance of:						
36s combed yarn, index	4	- .628	Yes	3	- .612	Yes
50s combed yarn, index	4	- .630	Yes	3	- .617	Yes
80s combed yarn, index	4	- .598	Yes	3	- .594	Yes
All combed yarn, index	4	- .589	Yes	3	- .578	Yes
Neps in card web, number	3	+ .579	Yes	3	+ .575	Yes
Card waste, percent	2	- .812	Yes	2	- .823	Yes
Comber waste, percent	4	+ .381	Yes	5	+ .406	Yes
Card and comber waste, percent	7	- .198	No	7	- .180	No

1/ The sign indicates the direction of the net contribution of rate of card production to the various dependent variables.

Table 17.--Summary of relative net importance of percentage of mature fibers to various dependent variables, as evaluated by multiple correlation analyses

Dependent variable	Percentage of mature fibers with--					
	Sorter series			Fibrograph series		
	Rank	Beta coefficient 1/	Statistically significant	Rank	Beta coefficient 1/	Statistically significant
Strength of:						
36s combed yarn, pounds	4	+0.103	Yes	4	+0.100	Yes
50s combed yarn, pounds	3	+ .136	Yes	3	+ .124	Yes
80s combed yarn, pounds	3	+ .168	Yes	4	+ .156	Yes
All combed yarn, CSP	4	+ .120	Yes	4	+ .112	Yes
Appearance of:						
36s combed yarn, index	6	+ .060	No	7	- .018	No
50s combed yarn, index	6	+ .109	No	7	+ .044	No
80s combed yarn, index	7	+ .043	No	7	+ .032	No
All combed yarn, index	7	+ .067	No	8	+ .018	No
Neps in card web, number	4	- .159	No	6	- .194	No
Card waste, percent	7	- .084	No	7	- .050	No
Comber waste, percent	5	- .243	No	6	- .388	Yes
Card and comber waste, percent	4	- .301	No	5	- .420	Yes

1/ The sign indicates the direction of the net contribution of percentage of mature fibers to the various dependent variables.

Table 18.--Summary of relative net importance of fiber length to various dependent variables, as evaluated by multiple correlation analyses

Dependent variable	Fiber length expressed as--					
	Upper quartile length (sorter)			Upper half mean length (fibrograph)		
	Rank	Beta coefficient 1/	Statistically significant	Rank	Beta coefficient 1/	Statistically significant
Strength of:						
36s combed yarn, pounds	1	+0.627	Yes	1	+0.760	Yes
50s combed yarn, pounds	1	+ .603	Yes	1	+ .818	Yes
80s combed yarn, pounds	1	+ .669	Yes	1	+ .856	Yes
All combed yarn, CSP	1	+ .557	Yes	1	+ .715	Yes
Appearance of:						
36s combed yarn, index	3	- .692	No	6	- .234	No
50s combed yarn, index	3	- .690	No	6	- .212	No
80s combed yarn, index	2	- .964	Yes	4	- .366	No
All combed yarn, index	3	- .742	Yes	6	- .257	No
Neps in card web, number	7	- .109	No	4	- .563	No
Card waste, percent	4	- .366	No	4	- .360	No
Comber waste, percent	1	-1.916	Yes	1	-2.447	Yes
Card and comber waste, percent	1	-2.155	Yes	1	-2.676	Yes

1/ The sign indicates the direction of the net contribution of fiber length to the various dependent variables.

Table 19.--Summary of relative net importance of fiber length distribution to various dependent variables, as evaluated by multiple correlation analyses

Dependent variable	Fiber length distribution expressed as--					
	Coef. length variability (sorter)			Uniformity ratio (fibrograph)		
	Rank	Beta coefficient 1/	Statistically significant	Rank	Beta coefficient 1/	Statistically significant
Strength of:						
36s combed yarn, pounds	6	+0.020	No	7	+0.017	No
50s combed yarn, pounds	7	- .003	No	6	+ .052	No
80s combed yarn, pounds	7	+ .007	No	6	+ .048	No
All combed yarn, CSP	6	+ .007	No	7	+ .035	No
Appearance of:						
36s combed yarn, index	5	- .119	No	4	+ .373	Yes
50s combed yarn, index	5	- .121	No	4	+ .336	Yes
80s combed yarn, index	5	- .119	No	5	+ .211	No
All combed yarn, index	6	- .114	No	5	+ .293	Yes
Neps in card web, number	5	- .155	No	7	- .182	No
Card waste, percent	6	- .085	No	6	- .173	No
Comber waste, percent	6	- .199	No	7	+ .307	No
Card and comber waste, percent	6	- .257	No	6	+ .181	No

1/ The sign indicates the direction of the net contribution of fiber length distribution to the various dependent variables.

Table 20.--Summary of relative net importance of fiber fineness to various dependent variables, as evaluated by multiple correlation analyses

Dependent variable	Fiber weight per inch with--					
	Sorter series			Fibrograph series		
	Rank	Beta coefficient 1/	Statistically significant	Rank	Beta coefficient 1/	Statistically significant
Strength of:						
36s combed yarn, pounds	2	-0.241	No	2	-0.158	No
50s combed yarn, pounds	2	- .407	Yes	2	- .267	Yes
80s combed yarn, pounds	2	- .470	Yes	2	- .348	Yes
All combed yarn, CSP	3	- .329	Yes	3	- .228	Yes
Appearance of:						
36s combed yarn, index	2	+ .909	Yes	1	+1.287	Yes
50s combed yarn, index	2	+ .842	No	1	+1.221	Yes
80s combed yarn, index	3	+ .735	No	1	+1.146	Yes
All combed yarn, index	2	+ .789	Yes	1	+1.160	Yes
Neps in card web, number	1	-1.028	No	1	-1.354	Yes
Card waste, percent	1	- .967	Yes	1	-1.019	Yes
Comber waste, percent	3	- .656	No	3	- .875	No
Card and comber waste, percent	2	-1.334	No	2	-1.587	Yes

1/ The sign indicates the direction of the net contribution of fiber weight per inch to the various dependent variable.

Table 21.--Summary of relative net importance of fiber strength to various dependent variables, as evaluated by multiple correlation analyses

Dependent variable	Fiber strength with--					
	Sorter series			Fibrograph series		
	Rank	Beta coefficient 1/	Statistically significant	Rank	Beta coefficient 1/	Statistically significant
Strength of:						
36s combed yarn, pounds	3	+0.140	No	3	+0.100	No
50s combed yarn, pounds	5	- .012	No	5	- .072	No
80s combed yarn, pounds	4	- .141	No	3	- .193	No
All combed yarn, CSP	7	- .005	No	6	- .050	No
Appearance of:						
36s combed yarn, index	1	+1.245	Yes	2	+1.163	Yes
50s combed yarn, index	1	+1.176	Yes	2	+1.080	Yes
80s combed yarn, index	1	+1.305	Yes	2	+1.146	Yes
All combed yarn, index	1	+1.181	Yes	2	+1.075	Yes
Neps in card web, number	2	- .790	No	2	- .668	No
Card waste, percent	3	- .527	No	3	- .559	No
Comber waste, percent	2	+ .943	No	2	+1.178	Yes
Card and comber waste, percent	3	+ .561	No	3	+ .770	No

1/ The sign indicates the direction of the net contribution of fiber strength to the various dependent variables.

Table 22.—Summary of relative net importance of grade of cotton to various dependent variables, as evaluated by multiple correlation analyses

Dependent variable	Grade of cotton with--					
	Sorter series			Fibrograph series		
	Rank	Beta coefficient	Statistically significant	Rank	Beta coefficient	Statistically significant
		1/			1/	
Strength of:						
36s combed yarn, pounds..........	7	+0.014	No	5	-0.081	Yes
50s combed yarn, pounds..........	6	+ .010	No	4	- .107	Yes
80s combed yarn, pounds..........	5	- .032	No	5	- .150	Yes
All combed yarn, CSP.............	8	- .002	No	5	- .100	Yes
Appearance of:						
36s combed yarn, index...........	7	- .056	No	5	- .250	No
50s combed yarn, index...........	7	- .048	No	5	- .228	No
80s combed yarn, index...........	6	+ .046	No	6	- .088	No
All combed yarn, index...........	8	- .019	No	7	- .181	Yes
Neps in card web, number...........	6	+ .145	No	5	+ .476	Yes
Card waste, percent................	5	+ .126	No	5	+ .293	Yes
Comber waste, percent..............	7	+ .178	No	4	+ .413	Yes
Card and comber waste, percent.....	5	+ .266	No	4	+ .616	Yes

1/ The sign indicates the direction of the net contribution of grade of cotton to the various dependent variables.

Table 23.—Summary of relative net importance of yarn size to count-strength product and yarn appearance, as evaluated by multiple correlation analyses

Dependent variable	Size of yarn with--					
	Sorter series			Fibrograph series		
	Rank	Beta coefficient	Statistically significant	Rank	Beta coefficient	Statistically significant
		1/			1/	
Count-strength product of all sizes of combed yarn, CSP...............	2	-0.473	Yes	2	-0.473	Yes
Appearance of all sizes of combed yarn, index.......................	5	- .307	Yes	4	- .307	Yes

1/ The sign indicates the direction of the net contribution of size of yarn to the respective dependent variables.

Table 24.--Comparison of values of coefficient of correlation obtained from multiple correlation analyses for 6 elements of raw cotton quality and rate of card production with various dependent variables, representing the carded yarn series of cottons and the combed yarn series, and including alternative fiber length measures

Dependent variable	Factors 1/	Observations in--		Coefficient of multiple correlation ($\bar{R}$) with--					
				Sorter length measures for--			Fibrograph length measures for--		
		Carded series	Combed series	Carded series	Combed series	Difference (6)-(5)	Carded series	Combed series	Difference (9)-(8)
	Number	Number	Number						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Strength of 14s yarn	7	60	--	0.945	-----	-----	0.970	-----	-----
Strength of 36s yarn	7	60	44	.949	0.989	+0.040	.975	0.994	+0.019
Strength of 50s yarn 2/	7	60	44	.953	.984	+ .031	.977	.993	+ .016
Strength of 80s yarn	7	--	44	-----	.980	-----	-----	.980	-----
C x S product of all yarn sizes	3/ 8	222	132	.965	.988	+ .023	.979	.993	+ .014
Appearance of 14s yarn	7	60	--	.852	-----	-----	.847	-----	-----
Appearance of 36s yarn	7	--	44	-----	.840	-----	-----	.874	-----
Appearance of 50s yarn 4/	7	60	44	.958	.847	- .111	.961	.871	- .090
Appearance of 80s yarn	7	--	44	-----	.852	-----	-----	.827	-----
Appearance of all yarn sizes	3/ 8	222	132	.918	.876	- .042	.918	.885	- .033
Neps per 100 sq. in. of card web	7	60	44	.814	.714	- .100	.838	.743	- .095
Percentage of card waste	7	60	44	.899	.869	- .030	.897	.882	- .015
Percentage of comber waste	7	--	44	-----	.618	-----	-----	.767	-----
Percentage of card and comber waste	7	--	44	-----	.534	-----	-----	.694	-----

1/ The 6 elements of raw cotton quality used in the analyses were as follows:

(Sorter series) Upper quartile length, coefficient of fiber length variability, fiber fineness, fiber strength, percentage of mature fibers, and grade index.
(Fibrograph series) Upper half mean length, length uniformity ratio, fiber fineness, fiber strength, percentage of mature fibers, and grade index.

2/ Three of the 10 varieties of cotton in the carded yarn series were too short to spin commercially into 50s yarn. Strength of 50s yarn in these cases was estimated from strength of 36s yarn by formula in order that the correlation results from analysis with 50s carded yarn would be comparable to those from analyses with 14s and 36s carded yarn.

3/ When count-strength product of all yarn sizes or when appearance of all yarn sizes was used as the dependent variable, yarn size was included in the analysis as an independent variable along with the other independent variables so used.

4/ In this analysis for the carded yarn series, appearance of the finest yarn spun from each of the 10 cottons was used as the dependent variable. It was yarn of size 36s in the case of the 3 shortest cottons and 50s for the 7 longer cottons. The results of this analysis, however, are identified in this summary table for comparative purposes with the combed yarn series as "Appearance of 50s yarn", because 70 percent or a majority of the yarns in the carded series actually were 50s.

Table 25.--Comparison of percentages of variance explainable in various dependent variables by 6 elements of raw cotton quality and rate of card production, as obtained from multiple correlation analyses representing the carded yarn series of cottons and the combed yarn series, and including alternative fiber length measures

Dependent variable	Factors 1/	Observations in--		Coefficient of multiple determination (R^2 x 100) with--					
		Carded series	Combed series	Sorter length measures for--			Fibrograph length measures for--		
				Carded series	Combed series	Difference (6)-(5)	Carded series	Combed series	Difference (9)-(8)
(1)	Number (2)	Number (3)	Number (4)	Percent (5)	Percent (6)	Percent (7)	Percent (8)	Percent (9)	Percent (10)
Strength of 14s yarn	7	60	--	89.4	----	-----	94.2	----	-----
Strength of 36s yarn	7	60	44	90.0	97.9	+ 7.9	95.0	98.7	+ 3.7
Strength of 50s yarn 2/	7	60	44	90.8	96.8	+ 6.0	95.5	98.6	+ 3.1
Strength of 80s yarn	7	--	44	----	96.1	-----	----	97.6	-----
C x S product of all yarn sizes	3/ 8	222	132	93.1	97.7	+ 4.6	95.8	98.6	+ 2.8
Appearance of 14s yarn	7	60	--	72.7	----	-----	71.8	----	-----
Appearance of 36s yarn	7	--	44	----	70.5	-----	----	76.4	-----
Appearance of 50s yarn 4/	7	60	44	91.7	71.8	-19.9	92.4	75.8	-16.6
Appearance of 80s yarn	7	--	44	----	72.6	-----	----	68.4	-----
Appearance of all yarn sizes	3/ 8	222	132	84.2	76.8	- 7.4	84.3	78.2	- 6.1
Neps per 100 sq. in. of card web	7	60	44	66.2	50.9	-15.3	70.2	55.2	-15.0
Percentage of card waste	7	60	44	80.9	75.4	- 5.5	80.5	77.8	- 2.7
Percentage of comber waste	7	--	44	----	38.2	-----	----	58.8	-----
Percentage of card and comber waste	7	--	44	----	28.6	-----	----	48.2	-----

1/ The 6 elements of raw cotton quality used in the analyses were as follows:

(Sorter series) Upper quartile length, coefficient of fiber length variability, fiber fineness, fiber strength, percentage of mature fibers, and grade index.
(Fibrograph series) Upper half mean length, length uniformity ratio, fiber fineness, fiber strength, percentage of mature fibers, and grade index.

2/ Three of the 10 varieties of cotton in the carded yarn series were too short to spin commercially into 50s yarn. Strength of 50s yarn in these cases was estimated from strength of 36s yarn by formula in order that the correlation results from analysis with 50s carded yarn would be comparable to those from analyses with 14s and 36s carded yarn.

3/ When count-strength product of all yarn sizes or when appearance of all yarn sizes was used as the dependent variable, yarn size was included in the analysis as an independent variable along with the other independent variables so used.

4/ In this analysis for the carded yarn series, appearance of the finest yarn spun from each of the 10 cottons was used as the dependent variable. It was yarn of size 36s in the case of the 3 shortest cottons and 50s for the 7 longer cottons. The results of this analysis, however, are identified in this summary table for comparative purposes with the combed yarn series as "Appearance of 50s yarn", because 70 percent or a majority of the yarns in the carded series actually were 50s.

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